A

# GENERAL SYSTEM

OF

# CHEMISTRY,

*THEORETICAL AND PRACTICAL.*

DIGESTED AND ARRANGED, WITH A PARTICULAR VIEW TO ITS APPLICATION TO THE ARTS.

TAKEN CHIEFLY FROM THE GERMAN OF M. WIEGLEB.

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BY

C. R. HOPSON, M. D.

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*LONDON:*

PRINTED FOR G. G. J. and J. ROBINSON, PATER-NOSTER ROW.

M.DCC.LXXXIX.

RC-E3282
R54E01

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PREFACE.

# PREFACE.

THE author of the Treatiſe, of which the following ſheets are a tranſlation, is M. *Wiegleb* apothecary at Langenſalza in Thuringia. It is well known, that the apothecaries in Germany, partly on account of their being accuſtomed themſelves to prepare the very numerous articles of their Diſpenſaries, and ſtill more perhaps in conſequence of the ſtrict examination they are obliged to undergo before they are admitted to practiſe the Pharmaceutic art, are, generally ſpeaking, poſſeſſed of more chemical knowledge than any other body of men in that country; and the names of *Kunkel*, *Neumann*, *Marggraf*, *Scheele*, and *Spielmann*, will deſcend to poſterity, in company with thoſe of *Becher*, *Stahl*, *Hoffmann*, *Pott*, and *Cramer*, with equal luſtre and undiminiſhed authority.

The original of the preſent work, notwithſtanding the numerous Syſtems of Chemiſtry that have of late been publiſhed in Germany, has nearly paſſed through two large editions in the ſpace of a few years. Nor will this perhaps be wondered at, when it is conſidered that, beſides its intrinſic value, it has the additional merit of being the only elementary treatiſe,* in which the ſubject is preſented in

* M. *Weigel*'s very valuable "Outlines of pure and mixed Chemiſtry, Griefswald, 1777," is the firſt work that was publiſhed upon this plan; but the Treatiſe is not elementary. Very lately alſo Profeſſor *Tychſens*, of *Copenhagen*, publiſhed a Syſtem of Chemiſtry, arranged in a ſimilar manner.

a method that not only renders it plain and perſpicuous to ſtudents in general, but alſo enables artiſts of every denomination to take in at one view the whole of the object of their reſpective reſearches. It was this conſideration chiefly that induced the Editor, in hopes of diffuſing a knowledge of Chemiſtry among the manufacturers and artiſts of his own country, to procure a tranſlation of the following Treatiſe; to which, that at the ſame time, it might be equally uſeful to the mere philoſophical ſtudent, he has added an Inroduction and Notes, chiefly illuſtrative of the principles and theory of the art.

In order to make room for theſe additions, the Editor was obliged to omit the greater part of the author's Theory, as well as almoſt the whole of his Introductory part, containing a ſhort view of Natural Hiſtory; both which, it is preſumed, might well be ſpared; the former, as being partly obſolete and partly falſe, and the latter, as being in a great meaſure foreign to the ſubject. Of theſe alterations and additions, therefore, it will be proper to give the reader ſome account.—The Diſſertation on Specific Heat was written, at the Editor's requeſt, by M. *Gadolin*, Profeſſor of Chemiſtry at Abo in Finland. For many of the notes, and particularly thoſe marked D, the Editor is obliged to Mr. *Dollfuſs*. The account given of the Gaſes, in the Introductory part of the work, is chiefly taken, mutatis mutandis, from *Fourcroy*'s Chemiſtry, excepting where the Editor's theory differed materially from that of this laſt author. The characters of the different Earths are given from M. *Wiegleb* himſelf, though with many alterations. All the reſt, as far page 65, as well as from p. 127 to 133, is furniſhed by the Editor. Of the laſt book, for the ſake of uniformity, intitled, *Philoſophical Chemiſtry*, but which ſhould rather have been ſtiled, *Fragments of Philoſophical Chemiſtry*, the firſt chapter, as well as the general arrangement of the whole, is by the Editor; as are all the Tables that are exhibited in the courſe of the work, thoſe only excepted that are annexed to the Analyſis of Mineral Waters.

With

With reſpect to the theory which the Editor has every where in the courſe of the following Treatiſe ſubſtituted for the author's, he has only to ſay, that the *baſis* of it is the fruits of more than twenty years meditation on the ſubject; and was ſubmitted by him to the judgment of the public, in the year 1781, under the title of an *Eſſay on Fire*. Now, as not only almoſt every fact that has occurred in Chemiſtry and Natural Philoſophy ſince the former of theſe periods, is to be explained conſiſtently with that theory, but likewiſe the principal features of it are now admitted by a great number of philoſophers, perhaps it will not be thought very preſumptuous in him, to offer it to the public in its preſent ſyſtematic garb. In fact, the idea of fire being a compound of heat and light, though not uniformly attended to as much as it deſerves, nevertheleſs ſeems, in ſome meaſure, at preſent, to pervade all Europe; and even that of phlogiſton, being nothing more than light and heat fixed in bodies, appears to gain ground daily with the philoſophic world, and is likely to excite the public attention more, ſince a celebrated German profeſſor has taken up the doctrine, and given it the paſsport of his name.

As to the doctrine of the generation of acids by the abſorption of air, the Editor, notwithſtanding the diſcoveries of M. *Lavoiſier* on this ſubject, does not heſitate to claim it for his own. It occurred to him ſo early as the year 1768, when he firſt adopted his preſent Theory of Fire, and was confirmed to him in the firſt inſtance by Dr. *Prieſtley*'s experiment of the abſorption of air by burning ſulphur, and the conſequent generation of vitriolic acid, mentioned in his firſt volume. But this fact, together with the manifeſt ſeparation of air from nitre in various operations, were almoſt the only foundations on which this hypotheſis could be ſaid to reſt, till the publication of *Scheele*'s admirable *Treatiſe on Air and Fire*, together with his Memoir on Arſenic, threw a new light on this intricate ſubject.



The

The Editor now, more than ever, convinced of the truth of his hypothefis, defigned, as was well known to many of his friends, to have added a chapter to his Effay, under the title of *Conjectures on the Generation of Acids*; but was at that time prevented from entering upon the fubject, from the confideration that, till the compofition of the aerial acid was known, the theory muft neceffarily be incomplete. Some veftiges, however, of this theory may be feen in the work abovementioned; and foon after the publication of it, he communicated his Syftem, imperfect as it was, to his late unfortunate friend, Dr. *Price*, of Guildford, who had long been acquainted with his fentiments on that and moft other chemical fubjects. But while, mifled by the fpecious doctrine of the production of fixed air from common air and phlogifton, he was vainly endeavouring, upon a fimilar principle, to account for the generation of this acid, which, however, it was evident to him, from the obfervations of *Scheele*, *Bergman*, and *Fontana*, was produced in oils by the admixture of air; M. *Lavoifier*, who, having long entertained an idea fimilar to that of the Editor, concerning the conftitution of acids, feems to have been as attentive to the appearance of new facts and difcoveries, as diligent in verifying them, publifhed his celebrated Syftem in the Memoires de l'Acad. des Sciences. Still, however, the origin of the aerial acid lay buried in obfcurity, till Mr. *Cavendifh*, in his excellent Paper on Air, publifhed in the 74th Vol. of the Phil. Tranf. page 119, plainly fhewed, that it was owing to the combination of the vegetable or organic principle with air; or, at leaft, this induction might be fairly made, and indeed was made by the Editor, from the pofitions laid down by that acute philofopher: and, M. *Lavoifier* himfelf afterwards completed the Syftem, by fhewing how this acid was formed in fermenting bodies.—With the modification of this Syftem by M. *de Morveau*, the Editor was fo little acquainted, that till very lately he concluded it to be the fame with his own, from which however it materially differs.

The

The new Nomenclature, likewiſe, that appears in this work, bears a ſtrong reſemblance to that publiſhed ſome years ago by M. *de Morveau*; but, excepting the names of the newly-diſcovered ſubſtances, and the ſubſtitution of the term *Spodium* for *Phytokali*, was ſhewn to Dr. *Price*, (nearly at the time with his Definition of Chemiſtry) in the year 1778, in the ſtate in which it is exhibited at pages 49 and 50; and was indeed drawn up at that gentleman's requeſt, in conſequence of ſome converſation that had paſſed upon the ſubject, between him and the Editor, then reſident at Guildford. It was likewiſe ſhewn three years afterwards to ſeveral literary gentlemen at Colcheſter; and the plan upon which it is drawn up was indicated by the Editor in the year 1782 to Dr. *Schwediauer*, who was then about publiſhing a Table of Salts, arranged and denominated according to *Bergman*'s firſt Syſtem. The Editor is happy to find his ideas concerning this matter coincide with thoſe of ſeveral men of learning and genius, who have very lately publiſhed Strictures and Criticiſms in the Journal de Phyſique, on the new French Nomenclature: but, the truth is, that very early in the courſe of laſt year the work was printed off much farther than the pages here referred to, and put into the hands of thoſe excellent chemiſts, M. *Goettling*, of Weimar, and Profeſſor *Gadolin*, of Abo, in Finland: So that the Editor could not have profited by the Strictures of the critics abovementioned, even had he been inclined blindly to follow precepts which, in ſome inſtances, appear to have been dictated leſs by an attachment to truth, than by a ſpirit of oppoſition. The term *Barytes* he has adopted from the illuſtrious *Bergman*, as being leſs awkward than Barogeum, (which he had made uſe of at firſt, and which has ſince been recommended by M. *Sage*) and more claſſical than *Barotes*, the appellation by which Heavy Earth was diſtinguiſhed by M. *de Morveau*. He has likewiſe ſince, for the ſake of uniformity, employed the ſame termination to all the other earths, except the Calcareous. For the

uſe

use of terms derived from the Greek language, he is fenfible that in Britain, no apology is neceffary.

From the charge of plagiarifm, with refpect to the doctrine of the formation of water, Profeffor *Gadolin* himfelf, who undoubtedly, prior to him, conceived and publifhed this Theory, can beft exculpate him. In fact, the Editor had undertaken, and even begun the following Commentary, long before he was convinced of the truth of the difcovery which reflects fo great, and perhaps an equal degree of honour upon Meffrs. *Cavendifh*, *Lavoifier*, and *de la Place*. It was not till the beginning of November 1787, that having read M. *de Fourcroy's* excellent expofition of the doctrine above alluded to, and amazed at the agreement which (contrary to his former prejudices) he now obferved to fubfift between all its parts, as well as the eafe with which many of the moft important phenomena in nature were explained by it, he was ftruck with the idea, that it might not only be made to accord with the doctrine of Phlogifton, but even could not fubfift without this addition. This difcovery, as he then fuppofed it to be, he inftantly communicated to his friend, Profeffor *Gadolin*, whom he knew to be a favourer of M. *Lavoifier's* doctrine, and was not a little furprized to find that this gentleman had already, in the preceding Spring, fent a paper containing a Theory, exactly fimilar to his, to Dr. *Crell*, of Helmftadt, to be inferted by him in the Chemical Annals. But, indeed, neither the Editor, nor the learned Profeffor, could properly lay claim to the difcovery, as it was already to be found in *Fourcroy's* Chemiftry; though fo obfcurely expreffed, that the Editor did not at all attend to it on his firft perufal of that valuable Treatife. However this be, it is by the Editor only that this doctrine has been propofed ferioufly, and infifted on uniformly; the other two gentlemen having brought it forward at firft doubtingly, and the one having fince formally, and the other virtually, renounced it.

The

The Editor will now put an end to this long addrefs, by fuppli-cating the indulgence of the public for the numerous defects of the following tranflation, but particularly for thofe which affect the ftyle. For thefe it may be thought fome excufe to alledge, that the ftyle of the original, which is flovenly, yet embarraffed, and though quaint, tedious, could not but in fome degree affect the tranflation. The perfon too, into whofe hands the work was put for this purpofe, was a ftill greater ftranger to Chemiftry than he was, though a foreigner, to the Englifh language; and the Editor, confcious with the Author that it is the matter, not the manner, that ftamps a value on performances of this kind, was not always extremely folicitous to cull the choiceft phrafes, or to give the higheft polifh to the periods of a Treatife, of which utility is the fole object, and confequently fhould conftitute the higheft praife.

*London, February* 10*th*, 1789.

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## DIRECTIONS to the BOOKBINDER.

The Bookbinder is defired to place the Table containing the Claffes and Genera Salium after page 50.—The Table of Chemical Operations after page 128.—The two Tables of Attractions, and the two Plates at the end of the Book.

# ERRATA.

*Few of the preceding sheets having been revised a second time by the Editor, the number of typographical errors is greater than might have been wished. The most material of them are as follow:*

Page 9, line 13, *for* qualities *read* quantities——p. 13, l. 12, *read* Heat in consequence of the properties with which it is endued, having——l. penult. *dele* or, *and read* to a known number of those degrees——p. 17, l. 5, *for* estimation *read* estimate——p. 31, l. 20, *after* fluor *read* acid——p. 44, l. 8 from bottom, *before* is *dele* it——p. 48, l. 8, *for* to *read* into————l. 4 and 5 from bottom, *dele* or Cawk——p. 49, l. 17, *for* Melecratia *read* Melocratia——p. 49, l. 24, *for* Galamelicratia *read* Galameliticratia—— ——l. penult. *for* Galamelicrates *read* Galameliticrates——p. 58, *between* l. 4 and 5, *insert* Sugar of Milk——p. 72, l. 4 from bottom, *for* Tin *read* Iron——p. 77, l. 7 from bottom, *read* The Edinburgh New Dispensary, printed for Elliot and Kay in the Strand——p. 85, l. 12 from bottom, *for* assaying *read* Cupellation——p. 116, l. 6, *dele* an——p. 129, l. 15, *for* revised *read* revived——p. 131, l. 19, *for* Arsenic *read* arsenical acid——p. 137, l. 9, *after* separation *read* or else, *and dele the following* or——p. 139, l. 19, *for* particular *read* particulars——p. 147, l. ult. *for* pecificsic *read* Specific——p. 169, l. ult. *for* Barylithicum *read* Barylithium——p. 172, l. 9, *dele* bring——p. 208, l. 18, *for* mines *read* Ertzgebirge——l. 22, *before* Sea water *dele* the——p. 249, l. penult. *after* mother-water *read* or *Bittern*——p. 253, l. 6 from bottom, *for* posely *read* purposely——p. 253, l. 4 from bottom, *for* accidentally *read* adventitiously——p. 256, l. 4, from bottom, *for* Barolithic *read* Barylithic——p. 260, l. 14, *for* keeps it in the Solution *read* holds it in solution——p. 266, l. 14, *after* called *read common Indian red*, by the Germans simply *brown red*——p. 293, l. 1 of the note, *before* verdigrise *read* crystallized——p. 295, l. 5, *for* promiscuously *read* previously——p. 320, *Note omitted after* Alga marina, l. 21. The author probably means the *Ulva latissima L.* ceu *Alga Saccharina Stromeri.* [E]——p. 325, l. 5 from bottom, *after* Starkey's Soap *read* is——p. 336, l. 2, *for* it is designed *read* according to its designation.——p. 336, l. 3, *for* on *read* by——l. 8, *for* all its properties *read* all the properties of lime——p. 337, 9, *for* Guter *read* Guhr——l. 15, *before* according *read* discriminated——p. 345, l. 11, *for* inflammation *read* deflagration——p. 335, *for* Toras *read* Tarras——p. 376, l. 1, *for* to *read* with——p. 381, l. 2, *before* glass *read* of——p. 386, l. antepenult. *dele* so——p. 400, l. ult. *for* of *read* for——p. 403, l. 13, *read stuck-ofens* or *piece-furnaces*——p. 416, l. 4 and 13, *after* separation *read* or parting—p. 423, 424, in sheet 3 I, *should be* 425, 426—p. 424, l. 8 from bottom, *before* Silver *read* for——p. 431, l. 7, *for* injecting the blood vessels, in certain cases, *read* in certain cases injecting the blood vessels——l. 12, *for* produces *read* produce—*for* argentam *read* Argentum——p. 432, l. 6, *read Platina purified and rendered ductile, being treated*——p. 464, l. 10, *before* glass *read* or——p. 480, l. 8, *for* described *read* distinguished—*after* their *read* different——l. 10, *read* which by this means impart to it——p. 490, l. 4, *for* or *read* and——l. 9, *for* quality *read* quantity——l. 14, *for* their *read* this——p. 491, l. penult. *for* preduct *read* products——p. 66, l. 23, *after* tea-cups *read* full——l. 26, *for* their *read* its——p. 516, l. 11 from bottom, *for* smaller *read* greater——p. 532, l. 13, from bottom *for* that we must *read* we must not——p. 547, l. 6 from bottom, *for* forms *read* forming——p. 552, l. 10, *for* sorrel *read* wood-sorrel——p. 565, l. 14, *for* is *read* are——p. 566. l. 3, *ead*-again, that ought to be white, from the ground in which it is fixed——p. 569, l. 9 from bottom *read* from whiting coloured with a strong decoction——p. 580, l. 5, *for* of hollow glass globes *read* with a view to form convex mirrors——p. 589, l. 23, *for* portion *read* proposition——p. 596, l. 20, *for* those that stand *read* he that stands.——p. 651, *for* Chap. VII. *read* Chap. VI.

In the 2d Table of Attractions, col. 16, *before* Cobalt *dele* ☿

Index——*under* Marine acid, *for* logisticated *read* dephlogisticated.

A GENERAL

A

# GENERAL SYSTEM

OF

# CHEMISTRY,

*THEORETICAL and PRACTICAL.*

---

## PART I. PURE CHEMISTRY.

---

### CHAP. I. THE OBJECT OF CHEMISTRY.

CHEMISTRY is the art of changing the properties of bodies by the tranſpoſition of their heterogeneous component particles*.

By particles are underſtood thoſe parts of a body which are too ſmall to be viſible or palpable, when ſingle or ſeparated from the body.

All bodies (the ſimple bodies called Elements alone excepted) conſiſt of *ſimilar* (or homogeneous), and *diſſimilar* (or heterogeneous) particles.

All bodies, and all the parts of bodies, mutually attract each other.

The mutual attraction of the *homogeneous* parts of bodies, is called the attraction of *cobeſion*.

* Conſidered as a *Science*, Chemiſtry may be termed, " The Knowledge of the Changes produced in the properties of bodies by the tranſpoſition of their heterogeneous component particles."

Chemiſtry may alſo be conſidered as the ſecond principal branch or grand diviſion of Phyſics or Natural Philoſophy, of which *Mechanics*, which conſequently may be defined " The knowledge of the changes produced in the properties of bodies by the tranſpoſition of their *homogeneous* component parts," form the firſt.



That

That ſubſiſting between the *heterogeneous* parts of the ſame body, as likewiſe between moſt *heterogeneous* bodies, is termed *chemical attraction*, and by ſome *affinity**.

And as the attraction exerted by one body on a ſecond is frequently found to be greater than the attraction ſubſiſting between this ſame body and a third, hence this ſpecies of attraction has obtained the name of *elective attraction*.

The tranſpoſition of the heterogeneous parts of bodies is effected by *chemical attraction* counteracting that of *coheſion*, and aſſiſted by the action of *heat*.

* The term, *Affinity*, though improper, as referring to an hypotheſis not yet proved, is yet more tolerable than any that might be taken from a ſuppoſed contrariety, oppoſition, conflict, or enmity ſubſiſting between the two ſubſtances; an opinion which, though evidently falſe, almoſt univerſally prevailed among the older Chemiſts. It may, therefore, be uſed occaſionally, for the ſake of preventing the too frequent repetition of the words " elective attraction."

## CHAP. II. THE SUBJECTS OF CHEMISTRY.

THE *ſubject* of Chemiſtry is all ſubſtances whatever, either natural or artificial, that occur on or near the ſurface of the terreſtrial globe.

Theſe may be diſtributed into eight different claſſes: 1. Heat; 2. Light; 3. Air; 4. Water; 5. Earths; 6. Salts; 7. Metals; 8. Combuſtibles; 9. the Mephitic Gaſes; 10. the Magnetic Fluid.

Of theſe ſubſtances, the three firſt, together with the firſt of the 9th claſs, are elements; all the reſt are compounds.

By the name of *elements*, we diſtinguiſh certain ſimple ſubſtances, of which all other bodies are compoſed, and which themſelves are not capable of being chemically decompoſed, or divided into different heterogeneous parts.

But beſides the four *genuine* and *manifeſt* elements alluded to above, there is a great number of others, which as they are never obtained alone, ſo as to be manifeſted to the ſenſes, and can only be traced by induction and reaſoning, may be called *ſpurious* or *occult* elements.

Theſe are as follow:

1. The baſe of Sulphur; 2. of Phoſphorus; 3. of the Muriatic acid; 4. of the Fluor acid; 5. of the acid of Borax; 6. the Organic baſe or Vegetable principle*, which is the common baſe of charcoal, oils, ſugar, the different vegetable and animal acids, the acid of amber, plumbago, and fleſh: and which, in certain circumſtances, always unites with pure air, with it forming the aerial acid; 7. the baſe of Gold, or earth of Gold; 8. of Silver; 9. of Copper; 10. of Iron; 11. of Tin; 12. of Lead; 13. of Platina; 14. of Mercury; 15. of Zinc; 16. of Manganeſe; 17. of Nickel; 18. of Antimony; 19. of Biſmuth; 20. of Cobalt; 21. of Arſenic; 22. of Molybdæna; 23. of Barylithium; 24. pure Siliceous Earth†; 25. pure Calcareous Earth; 26. pure Muriœcic Earth; 27. pure

* This in the following ſheets will be moſtly called the vegetable principle; as even when it is found in animal ſubſtances, it evidently proceeds from the vegetable kingdom.

† We have referred the five primitive earths, or rather their ſuppoſed baſes, to the occult elements, merely on the ſcore of their analogy with the calces of metals. It is true, even in the ſtate in which we find them, they may be conſidered as genuine elements, on account of their not having as yet been decompoſed; but from many other conſiderations they rather ſeem to come under the denomination of *mixts* or primary compounds.

Barytes; 28. pure Alumite*; 29. Hydrophlogium or the base of Water and inflammable Gas.

## SECT. I. Heat.

The first class of substances occuring on and near the surface of our globe, is constituted by *heat*. This element is not only perfectly fluid itself, but the very principle of all fluidity. It pervades all bodies, and in its passage through them expands and softens them; and, when it is present in sufficient quantity, melts, liquefies or fuses them, that is to say, renders them fluid in the first degree. But different substances require different quantities of the element of heat for this purpose. Without heat, all bodies must necessarily be solid. Being in some measure attracted by every substance in Nature, it enters into their interstices, and there diminishes the attraction of their particles, the power by which these substances cohere, and this in different degrees, according to the quantity in which it enters them, or (which is the same thing) the force with which they attract it. The immediate result of this congestion of heat in bodies is an augmentation of their specific gravity, and a more ready communication of this fluid to other substances in contact with them. In consequence of this latter circumstance, they are said to be hotter than those bodies which have attracted heat in smaller quantities. So long as this element continues to flow into a body no faster than it can flow out of it, it is but weakly attracted by the body through which it passes, and is free to act upon other bodies, and be acted upon by them, and consequently to enter their pores. But when it is present in a certain quantity (which quantity is different in different bodies) some part of it is attracted with an increased force in consequence of its having set the particles of the heated body at such a distance from each other, as to have considerably diminished their mutual attraction, and at the same time increased the internal surface; both which circumstances contribute to augment the attraction between it and the body. The visible consequence of this greater attraction taking place, is a change of form in the substance

* Volatile alkali, which is known to be a compound substance, being separable from the fixed alkalies; these latter must of necessity be likewise considered as compounds, and are consequently excluded from this list.—Of the nature and constitution of the magnetic fluid we know nothing. That it is not without its elective attractions, we have every reason at present to suppose; what these are, future experiments may probably teach us.

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ſtance thus acted on, and its converſion into a fluid; in which caſe, its interſtices being filled up by its newly-acquired fluid element, it is divided into very ſmall ſpherical particles, which having but a ſmall degree of coheſion, are moveable by the leaſt force, and eaſily roll over each other; and are therefore, by the power of gravity continually acting upon them, obliged to preſerve a level ſituation at the ſurface. A certain quantity of the element of heat being ſufficient to convert a ſolid body into that kind of fluid diſtinguiſhed by the name of *liquid*, a ſtill greater portion is required in order to throw the ſame body into the ſtate of *vapor:* when, if the heated body have a very ſtrong attraction for this elementary ſubſtance, it will even form a fluid, which in the preſſure of the atmoſphere near the ſurface of the earth, and the uſual cold of the climate of Europe, will be permanently elaſtic: and is diſtinguiſhed by the name of *gas*. Not that it is at all neceſſary that a ſolid, which is to be converted either into vapor or gas, ſhould paſs through the intermediate gradations. In fact, the contrary often happens. For if the attraction of the heated ſubſtance for heat be conſiderable, it will be converted into vapor, and even into permanent vapor (or gas) the inſtant it has quitted the ſolid form: of which volatile alkali (or ammonium) is an inſtance.

Heat thus quieſcent (though not abſolutely fixed) in bodies, is called *latent* heat. But it can hardly be conſidered as a principle or conſtituent part of theſe bodies: for when the form of the body is deſtroyed, its elective attractions and every other property remaining entire, the heat it had abſorbed reſuming its priſtine elaſticity, again becomes evident to the ſenſe, and is diffuſed through the neighbouring ſpaces in the ſame manner as before. Thus vapor gives out heat on returning to its priſtine form of water; and, on the other hand, water is ſenſibly hotter at the inſtant of its congelation, when it aſſumes the form and ſolidity of ice, than it is juſt before or after that period.

Heat is not transferable in its latent ſtate and alone from one body to another; but when fixed and in combination with light, in which ſtate it conſtitutes what is called phlogiſton, it is conſtantly transferred from ſubſtances into which air is entering, to others from which that element is making its eſcape.

To conclude this ſubject: In conſequence of the attraction of every ſubſtance in nature for heat, a certain portion of this element in a latent ſtate ſeems to be contained in, and even to form an atmoſphere about, all bodies. This is extricated from them by percuſſion and commenſtruation; or in other words, it is expelled from bodies by *preſſure*, (vid. *Eſſay on Fire*, page 33) on which occaſion

it becomes ſenſible. In conſequence alſo of bodies being already ſaturated or nearly ſaturated with this principle, the quantity of it which flows into them ab extra, cannot be attracted by them ſo as to be retained in them; but flows out almoſt as faſt as it enters. But when the heat is applied ab extra ſo faſt that it cannot readily make its eſcape out of the body, this latter is diſtended by it ſo much as to have its internal capacity greatly increaſed, and, conſequently, its attraction for heat proportionally augmented. The reſult is, a change from a ſolid to a liquid ſtate, or even to that of vapor; and, if the attraction of the body for heat be conſiderable, to that of gas, a ſpecies of vapor from which the latent heat cannot be ſeparated without a great degree of preſſure, or which is equivalent to it, a great degree of cold, or in other words, a conſiderable deficiency of active heat, which, now ceaſing to expand the body, the particles compoſing this latter are at liberty to approach each other ſo much nearer, as to be able to attract each other vigorouſly, and conſequently to expel the latent heat contained between them.

So that one great, if not the principal, effect of latent heat ſeems to conſiſt in rarefying bodies, and rendering them lighter than before. Hence the more volatile* bodies are, the more ſuſceptible they are of an acceſſion of latent heat, or, in other words, the better adapted to attract heat, ſo as to render it latent and imperceptible to the ſenſe†.

When heat is abſent from a body, that body is ſaid to be cold: whence cold has been conſidered as a real entity, and has been ſuppoſed to be in oppoſition

* Volatility is the property of receding from the centre of the earth on the application of heat, or it is that property, by which bodies are enabled to combine with heat, ſo as to form with it a fluid ſpecifically lighter than the atmoſphere. No body is abſolutely fixed, or unfuſible.

† The ſenſe here alluded to, is not the touch or ſenſe of feeling, which is confined to the ſkin, and chiefly to the nervous papillæ at the tips of the fingers, and by which the figure and reſiſtance of bodies are perceived; but a more univerſal perception than any of what are commonly termed the five ſenſes. Perhaps it is that by which pain is felt, and which is excited by any circumſtances occaſioning the diſtention of the nerves: and, although it bears ſome analogy to the reſt (as indeed they all do to each other) may be properly enough conſidered as a *ſixth* ſenſe. In ſhort, heat is a ſpecies of matter which acts on one ſenſe only, which ſenſe, however, cannot be properly called the ſenſe of *feeling*; for the preſence of heat does not enable us to judge either of the reſiſtance or figure of bodies. It is the identity of the word (*feeling*) uſed on both theſe occaſions that deceives us. Uſe the word *touch*, and the equivoque vaniſhes. We are then no longer deceived. For who talks of touching heat? that we can touch fire indeed, is frequently ſaid: but even by this is meant merely a body on fire or in the act of combuſtion.

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with heat, a ſuppoſition which has given riſe to many abſurd notions. Thus cold is ſaid to contract bodies, and to render them fragile, when, in fact, they contract and are fragile of themſelves, as ſoon as heat ceaſes to act upon them. So that, in reality, the force of cohesion, when uninterrupted, and not counteracted by other powers, is infinitely ſtronger than we are apt to imagine.

Before we quit this ſubject, we muſt be allowed to remark, that the word *fire*, however convenient the uſe of it is in common life, and particularly as ſerving to abridge our diſcourſe, has occaſioned much confuſion in Philoſophy. Thus Philoſophers, having once adopted this complex idea from the vulgar, have ſeldom ſince been able to ſeparate the ideas of which it is compoſed: and hence they have not only talked of bodies being expanded by fire, which is the caſe only when they are made red hot; but many of them have endeavoured farther to ſimplify the ſubject, by conſidering light and heat as conſtituting one and the ſame element of fire, but ſubſiſting in two different ſtates.

That heat is a peculiar matter, and not the motion of matter in general, we have aſſumed, after the chemical Philoſophers, men who are doubtleſs beſt acquainted with the ſubject, and yet have never appeared to entertain the leaſt doubt on this head. In fine, we appeal to our ſenſations, and to the obſervations of ſuch as have had the greateſt experience in this reſpect: leaving it to thoſe to prove the negative, who, ſwayed by their veneration for the great men as well at the early dawnings, as juſt before the preſent bright æra, which may juſtly be ſtiled the meridian of phyſical ſcience, have maintained the contrary opinion; upon whom likewiſe it is incumbent, rigorouſly and mathematically to demonſtrate what ſpecies of motion it is that is affected by matter, when it excites the ſenſation of heat.

## Specific Heat.

*As the ſubject of Specific Heat has for ſome years paſt greatly excited the attention of the Public, we are happy in being able to gratify the laudable curioſity of our Readers, by laying before them the following* Diſſertation, *written by a Friend, who, by the perſpicuous and truly philoſophical manner in which, in his former writings, he has treated the ſubject, has ſhewn himſelf perfectly equal to the taſk of promoting this Branch of Natural Knowledge.*

THE ſenſation of heat perceived by the human frame, is an effect proceeding from an inviſible cauſe, of which we have formed ſome idea, by other effects conſtantly produced upon adjacent bodies, at the ſame time that the ſenſation of heat is produced on our own. Theſe different effects we attribute conſequently to one and the ſame cauſe. Thus we ſay, that the cauſe of heat, by its preſence in a body, increaſes the bulk of the body, i. e. ſeparates its particles to ſome diſtance from each other, ſince we find that the increment of the bulk of a given body is always the ſame, when by our feelings we perceive that the cauſe of heat communicated to the body is conſtant and unvaried. Moreover we judge that by increaſing the intenſity of this cauſe to a certain point, the particles of the body are ſet at a diſtance beyond the reach of their coheſion.—In this caſe, the body being previouſly in a ſolid ſtate, is reduced to a ſtate of liquidity. And in like manner, we ſay, that the cauſe of heat, when preſent in a ſtill greater degree, cauſes a mutual repulſion between the particles of a body, which then is converted into an elaſtic fluid.

Theſe properties of the cauſe of heat are very analogous to impenetrability and the power of extenſion, which are univerſally conſidered as general properties of bodies: and as of all other effects attributed to the cauſe of heat, there is none yet known that may not be derived from a material cauſe; the opinion has been almoſt univerſally adopted, that the cauſe of theſe effects is material, which cauſe, therefore, is commonly called the *matter of heat*, or ſimply *heat*. But as there are ſome properties common to all bodies, that have not as yet been found in the cauſe of heat, I think it more proper to avoid giving it the appellation of matter, as this poſſibly might induce the mind to form erroneous conceptions of

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its nature: and therefore I have chosen to retain the former denomination, calling it the cause of heat; or for shortness, *heat* only; by this expression meaning nothing else than the cause of the effects above-mentioned, considered abstractedly from all its other effects: and when its effects with regard to our senses are considered, I call it *sensible heat*.

It is a well known fact, that when the sensible heat is accumulated in a body, it communicates itself by degrees to the adjacent bodies, until the equilibrium is restored. That is: the hotter body grows colder and colder, and the cold bodies warmer and warmer, till at last they meet at a common point at which each of them is able to excite the same degree of sensation of heat upon us. Thus if a hot body is plunged into cold water, or a cold body into warm water, the sensible heat will soon be equally divided between these two bodies.

The intensity of this acquired common heat depends upon the relative qualities of the bodies in communication with each other. A large quantity of water, when all the other circumstances are the same, communicates to a given body a greater quantity of sensible heat or cold than a small quantity is able to communicate to it. Again, if the quantity of water is the same, a large lump of a body, plunged into it, will alter its sensible heat more than a small piece of the same body could do: and if we conceive the quantity of this body to decrease, its power to alter the sensible heat of the water will, by continually decreasing, at length become imperceptible; or, in other words, the common heat of the body and the water, will in no perceptible degree differ from the sensible heat of the water previous to their mutual communication.

When a body in this state distinctly shews the increments or decrements of its sensible heat, by its increasing or decreasing bulk, it may serve for an instrument for measuring the sensible heats of other bodies. And on this principle are all our thermometers constructed.

As our senses are not delicate enough to distinguish between small variations of heat, but on the contrary, are often influenced by other circumstances, and liable to error; a good thermometer, where not only the bulk of the thermometric body at the same degree of heat is invariably the same, but its increase or decrease at small variations of heat are very sensible, is of great use in shewing the degrees of heat. These degrees, when determined by means of a thermometer with more precision than our feelings alone could distinguish, are, I think, not very properly called degrees of the sensible heat of a body; and, therefore, I prefer denoting them by the denomination of the body's *temperature*.

When it had once been aſcertained that the degree at which water boils, the preſſure of the air being given, as well as the degree at which it freezes, are invariable; there was no great difficulty in making thermometers of the ſame kind, the degrees of which would correſpond exactly with each other. Theſe correſponding degrees were found, after the two fixed points were determined and marked upon the thermometric ſcale, by dividing the diſtance between them into a given number of equal parts. But that the equal increments of the thermometric body (or thermometric liquor, as liquid bodies were found to be by far preferable to ſolids) repreſented by theſe equal diviſions were affected by equal increments of heat, was not as yet evident. On the contrary, it ſoon appeared that thermometers of different kinds, or the liquors of which were of a different nature, differed from each other: whence there was a ſtrong preſumption that none of them exactly repreſented an equal progreſſion of the heat.

However, by comparing together ſeveral different thermometric liquors, it was obſerved that thoſe which had their boiling or freezing points not very diſtant from the temperatures to be compared, were the moſt irregular, and deviating from each other as well as from thoſe of which the boiling and freezing points were more diſtant. On the other hand, thermometers depending upon the variation of the bulk of more permanent liquids, as mercury, linſeed oil, and air, agreed very nearly with each other. And hence there was great reaſon to believe that theſe liquors increaſe or decreaſe in their volume, nearly in proportion to the increment or decrement of their heat, or temperature.

This opinion has been fully verified by obſervations inſtituted upon this ſubject. Sir *Iſaac Newton* computed the decrements of the heat of bodies from the time in which it was gradually cooled in air of an uniform temperature, and found that theſe decrements correſponded very nearly with the decrements of the bulk of the linſeed oil, in his thermometer. After him others, and eſpecially the ingenious *Lambert*, made ſimilar obſervations with thermometers of mercury and air, and found the reſults to be the ſame. Others propoſed to mix liquors of different temperatures, and to obſerve the degree indicated for the mixture by the thermometer. As it was ſuppoſed that a certain quantity of hot water being mixed with an equal quantity of water that was colder, the mixture would acquire the exact mean temperature between them both. It alſo ſeemed very probable, that in this way a juſt compariſon might be made between the progreſs of heat and the degrees of the thermometer. And experiments having been made relative to this point,

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the accuracy of the indication of the mercurial, &c. thermometers was farther aſcertained.

It has therefore been univerſally taken for granted, that the degrees of the mercurial thermometer, (which now is almoſt the only one in uſe) repreſent the actual progreſſion of heat in a body, ſuch as water, for inſtance: That is to ſay, that the number of thermometric degrees to which a given quantity of water is heated, is proportional to the quantity of heat communicated to that water. So that, if of two equal quantities of water, to the one ten degrees of heat are communicated, and to the other but one degree, the heat added to the former is ten times as great as that added to the latter. Or, in other words, the ſame quantity of heat which is able to raiſe the temperature of a given quantity of water ten degrees, is exactly ſufficient to increaſe the temperature of ten times as much water by one degree.

Experiments of this kind have been repeated with great care, and with a variety of bodies, and the reſults have agreed in the ſame way, as often as any of the more ſimple liquids, ſuch as water, quickſilver, &c. have been uſed. The caſe has likewiſe been the ſame when theſe experiments have been made with ſolid bodies, for inſtance, when two portions of pounded chalk have been mixed together. (With regard to ſome other bodies, eſpecially thoſe of a more compound nature, exceptions have been found to take place; of which I ſhall take occaſion to make ſome mention in the ſequel.) Therefore, as the true repreſentation of heat by the thermometer was even before theſe experiments were made, nearly aſcertained, the agreement of theſe experiments with the theory, leaves no doubt of the truth of the abovementioned hypotheſis, viz. that heat may be conceived as a ſubſtance adhering to bodies: and that when two unequally heated quantities of the ſame body have been mixed together, it diffuſes itſelf equally, and unvaried with reſpect to quantity, through all the particles of the mixture, in a manner analogous to the diffuſion of a ſalt diſſolved in water, which when two unequally ſaturated ſolutions are mixed together, is found to be equally diſperſed among all the particles of the mixture.

The equal communication of heat between mixed bodies does not take place when theſe bodies are of different kinds. Thus, when equal quantities of mercury and water of different temperatures are mixed together, the temperature of the mixture will approach much nearer to that of the water than to that of the mercury. And if ſuch a proportion of theſe two bodies be deſired, that the temperature of the mixture may be repreſented by the exact mean of their previous temperatures, more than two parts of quickſilver in bulk muſt be taken to one

of water, or near 30 times as much quickſilver as the weight of the water amounts to. And in caſe this proportion between the quantities of mercury and water is obſerved, we always find the temperature of the mixture to be the exact mean between the temperatures of the two fluids. Now, from what has been ſaid in the preceding pages, we have no reaſon to doubt, that the whole quantities before and after the mixture are equal, and conſequently that what the mercury has loſt or gained is taken up or loſt by the water. In the abovementioned inſtance, therefore, the heat loſt or gained by 30 parts of mercury, when it is cooled or heated to a given number of degrees, is required to heat or cool one part only of water to the ſame number of degrees. Or, one part only of water, when it undergoes a change in its temperature, has the ſame effect in heating or cooling ſurrounding bodies as 30 parts have of quickſilver; and, conſequently, the heat which a given quantity of mercury loſes when reduced to a colder temperature, or which it acquires, when heated to a higher temperature, is equal to $\frac{1}{30}$ part of the heat, which an equal quantity of water loſes or acquires under ſimilar circumſtances.

If inſtead of mercury another body be mixed with water of a different temperature*, we find likewiſe, that equal quanties of both bodies being taken, the temperature thence ariſing is not the mean temperature; but that for this purpoſe, there is a certain portion of the quantities to be obſerved: for we very ſeldom meet with two bodies, which, when taken in equal quantities and under the ſame variations of temperature, are able to produce the ſame effects in heating or cooling other bodies, or which loſe or gain the ſame quantities of heat, when ſituated in the circumſtances abovementioned.

This relative property of different bodies is called their *capacity of receiving or communicating heat*, or their *capacity* only; and is eſtimated by *the proportion of the quantities of heat communicated or abſorbed by different bodies of the ſame weight undergoing an equal change in their temperatures, without ſuffering any alteration with reſpect to this communicating power.*

The capacity of a body is conſtant when its power of communicating or receiving heat is invariably the ſame; but if in higher temperatures there is conſtantly

* When experiments of this kind are to be made, care muſt be taken that the two bodies have no chemical action upon each other; as in this caſe, their compoſition being altered, their properties with regard to heat alſo generally undergo ſome change, in conſequence of which, the reſult of the experiment is different from what it would have been, if no change had taken place.

ſtantly either more or leſs heat communicated or abſorbed by a body cooled or heated to a given number of degrees, than when the ſame body undergoes an equal change at a lower temperature, its capacity is ſaid to increaſe or decreaſe gradually, while the temperature is increaſing.

We have ſeveral inſtances of bodies whoſe capacities are gradually varying: thus, for inſtance, linſeed-oil, ſeveral, or perhaps all ſaline ſolutions; a mixture of ſpirits of wine and water, a mixture of oil of vitriol and water, &c. have their capacities greater in a high than in a low temperature. But as my deſign at preſent is not to enter into an inquiry concerning the laws and cauſes of ſuch varieties, I ſhall now conſider only the more ſimple caſe of conſtant capacities.

## HYPOTHESIS I.

Heat, of the properties with which it is endued, in conſequence having been conſidered as a ſubſtance, has alſo been ſuppoſed to be definite with reſpect to quantity. Hence the Philoſophers have imagined a certain ſtate of bodies, in which theſe are deprived of the whole of their heat, or in which there is abſolute cold. Every body approaches nearer and nearer to ſuch a ſtate, when its temperature is decreaſing, or when the thermometric liquor applied to it decreaſes in volume. Therefore, if ſuch a ſtate exiſts, there muſt neceſſarily be a point on the thermometric ſcale repreſenting this temperature. This point is denominated *the loweſt point*, or the point of abſolute cold, or of abſolute privation of heat. And if the numeration of the degrees on the thermometric ſcale is begun from this point, theſe degrees are called the *abſolute degrees* of heat. Now, although we ſhall probably never have it in our power to ſee a body cooled down to this point, yet it is not impoſſible to determine, by calculation, the diſtance of it from another point repreſenting a known temperature; and although it is uncertain whether there can be found a ſubſtance which by uniform decrements of temperature continues to decreaſe uniformly in bulk, till it is arrived at the point of abſolute cold; yet the diſtance of this point being once found, the whole quantity of heat contained in a body of a given temperature may be eſtimated from the proportion of the whole number of degrees, (from the loweſt point to that temperature) or to a known number of ſuch degrees as thoſe that are perceived by us.

Let us ſuppoſe a body to have a conſtant capacity in all its temperatures, down to the loweſt point. Of ſuch a body, we are aſſured, that throughout the whole ſeries, it acquires or loſes equal quantities of heat, at each ſingle degree by which its temperatures are varied. We know that a given number of degrees repreſents as many times the quantity of heat acquired or loſt by a variation of one degree, as there are units compoſing that number. Hence it is evident, that the number of the abſolute degrees of heat indicates how many times the heat of one degree is contained in the body: or that the proportions of theſe degrees at different temperatures of a body, is the proportion of the whole quantities of heat contained in the body at thoſe temperatures. And if we conceive another body whoſe capacity likewiſe is conſtant, but different from that of the former; the ſame abſolute degrees will alſo repreſent the abſolute quantities of heat of that body. But the capacities of two bodies are proportionate to the quantities of heat acquired or loſt during a given change of temperature; for inſtance, that of one degree; and one degree is the ſame aliquot part of the abſolute number of degrees in both bodies, their temperatures being the ſame; conſequently, in this caſe, the capacities of theſe two bodies are proportionate to the whole quantity of heat contained in them.

Hence it follows that if a body, of a conſtant capacity, ſhould at any temperature, *by any cauſe whatſoever, and without the application of heat or cold, ab extra*, ſuddenly change its nature, and alter its capacity to another conſtant capacity likewiſe, but either greater or leſs than the former; this body muſt at the ſame time neceſſarily undergo a remarkable change in its temperature, and be heated or cooled in a conſiderable degree, according as its capacity is diminiſhed or increaſed: for, the abſolute quantity of heat in the body before the change and after it, at a common temperature, being in the proportion of their capacities, they muſt be unequal, ſuppoſing the body after the change to remain at the temperature at which the change took place; but, in fact, they cannot be unequal, as there was no heat nor cold applied ab extra. Therefore, the capacity being altered, an alteration in the temperature muſt likewiſe take place, ſo that the temperature muſt be higher when the capacity is decreaſed, and lower when it is increaſed.

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HYPOTHESIS II.

This conclufion, however, depends upon the hypothefis, that heat cannot be contained in a body in a ftate of combination; or that it can in no way entirely efcape our perception. For, if that were the cafe, increments and diminutions of the abfolute quantities of heat might take place in a body, without being inferred from any alteration of the fenfible heat or temperature. But it is extremely probable that heat never enters into a fimilar ftate of *inactivity*, i. e. into a ftate in which it is not perceptible; as not acting either upon our fenfes, or upon the thermometer, &c. In my Differtation *de Theoria Caloris corporum Specifici*, I have defcanted more at large upon this fubject. Here I will content myfelf with obferving, that fuch a ftate of this kind accords fo little with the notions we have of heat, that it ought by no means to be admitted as a fuppofition, unlefs it could ferve to explain facts not otherwife explicable. But this is not here the cafe. There is as yet no phenomenon known, which, having been examined with the utmoft care, has not been explained in a fatisfactory manner without fuch fuppofition, as will partly appear in the fequel.

We frequently meet with inftances of heat or cold produced on a fudden, when a body has changed its external appearance, either by folution or coagulation, or otherwife.

Dr. IRWINE examined the capacities of fuch bodies before and after thefe changes, and always found that the capacity had been converted into a leffer, when heat was produced, and into a greater, when there was a production of cold; whence he concluded, that the variations of temperatures were owing to the alterations of the capacities; and they laid the foundation of the whole theory of the fpecific heat of bodies, of which the principal dogm is, that there is never any heat or cold produced in nature, unlefs a change has taken place in the capacities of thofe bodies in which the variation of temperature originated.

Dr. CRAWFORD has very ingenioufly, as well as fuccefsfully, applied this doctrine to explain thofe grand natural phenomena, animal heat, and the combuftion of inflammable bodies. He found that pure air, in its elaftic ftate, poffeffes a greater capacity than any body yet known, and that it always lofes much of this capacity as foon as it is brought into another ftate. This air is the only air fit for refpiration, and, confequently, for fupporting animal life. But during refpiration, it is partly con-

converted in to fixed air or water, both of which have a great deal leſs capacity than pure air. Hence he could not doubt, but that the ſource of the heat, which is continually ſupplied in animals endowed with lungs, was in the air reſpired by them.—The ſame air is equally neceſſary for the inflammation of combuſtible bodies; and during their proceſs it combines with the combuſtible body, and forms new compounds, in which the capacity of the air is always remarkably diminiſhed.—Dr. CRAWFORD, not content with general reaſonings upon a ſubject of ſo great importance, has lately made ſome experiments with all poſſible care, in order to compare the quantity of heat ſet looſe during the combuſtion, and that which ought to have been perceived if the alteration of the capacities had been the only cauſe of the heat produced; and has found that the reſults of the obſerved and computed heat agreed very nearly. And I am happy to find that theſe experiments nearly agree in their reſults with thoſe which (though with different bodies, and in a different way) I with the ſame views made and publiſhed in *Sweden*, ſome years ago.

I ſhall not at preſent enter into a circumſtantial detail of theſe experiments, but as the ſubject is worthy the utmoſt attention, I ſhall endeavour to explain the principles upon which experiments of this kind, and the calculations made from them, are founded.

All my former reaſonings on the whole quantities of heat in a body, reſpect not only ſuch bodies in which the capacity is conſtant, as far as our obſervations carry us, but alſo thoſe in which it continues to be ſo, till the body is cooled down to the very loweſt point. Now, though there is ſome probability, that ſome ſolid bodies, which conſidered with reſpect to their external form, may reaſonably be ſuppoſed to perſevere in the ſame ſtate, at any degree of cold, and which, as far as our obſervation can reach, have their capacities unaltered; though it is ſomewhat probable, I ſay, that theſe bodies likewiſe continue to poſſeſs the ſame capacity in any lower temperature whatſoever; yet I am far from thinking this to be the caſe with all bodies. On the contrary, it is well known that many, when brought down to a certain temperature, change all at once their external appearance as well as their capacity. Others have been found to vary their capacities continually, and by imperceptible degrees, when their temperatures vary. Whence I think it not at all unlikely, that even the capacities of theſe bodies, which appears to be the moſt unvaried, might vary in a ſmall degree, ſo as to be perceptible by our ſenſes: as there is but a ſmall part of the thermometric ſcale on which we can conveniently make our obſervations. We are, therefore, entirely

in

in the dark concerning the capacities of bodies at lower degrees; and consequently cannot know with certainty the whole quantity of heat contained in any body, even if the lowest point were determined on the scale of the thermometer.

## HYPOTHESIS III.

In order therefore to arrive at some kind of estimation, a new hypothesis has been adopted, *viz. that the whole quantity of heat in a body, is equal to the quantity of heat which the body would contain, if it could be cooled down to the lowest point, its capacity being at the same time unchanged throughout the whole series.*

The quantity of heat of a body at any given temperature, thus estimated and compared with that of another body of an equal weight and at the same temperature, has been called the *comparative*, or *specific heat* of a body. I must confess, that I give the preference to this last denomination, as being more expressive, and more conformable to the common use of the epithet *specific*, in denoting the plus and minus of other relative qualities of bodies, expressible by numerical proportion.

As, therefore, according to this hypothesis, the absolute quantity of heat of a body at any given temperature, depends upon the temperature of it, and its capacity at that temperature; it evidently follows, that the specific heats of two bodies are always in proportion to their capacities at their common temperature, whatever the variations of their capacities may be at different temperatures. And when at any temperature a body alters its capacity, there must be heat or cold produced, according as the capacity is decreasing or increasing; and the quantity of heat produced or absorbed, expressing the difference of the whole quantities of heat in the body, before and after the alteration happened, is equal to the difference of the specific heats and proportionate to the difference of the capacities. If, therefore, this quantity is known, together with the two different capacities of the body, the whole quantity of the heat contained in the body may be determined by the ordinary rule of proportion, or Rule of Three; by saying, as the difference of the capacities is to the capacity before the variation, so is the quantity of heat set loose or absorbed, to the whole quantity of heat contained in the body before the change took place. Thus, for instance, we know that when ice at the freezing point is melted, there is a quantity of heat absorbed which does not affect the tem-


perature

ture of the ice, but is expended merely in rendering it liquid; this quantity of heat is by experience found to be equal to that contained in an equal quantity of water heated to near 146 degrees above the freezing point; (as if ſuch water be mixed with ſnow, the whole is juſt melted, and the temperature is ſtill that of the freezing point.) If farther, agreeably to Dr. *Irwine's* obſervation, we ſuppoſe that the capacity of water is to that of ſnow as 10 is to 9; we know by the third hypothesis that the ſpecific heats at the freezing point are in the ſame proportion; and conſequently that their difference is equal to one tenth of the heat contained in the water at the freezing point. But this difference is equal to the quantity of heat required to raiſe the temperature of an equal weight of water to 146 degrees; therefore, the whole quantity of heat contained in the water at the freezing point, is equal to the heat required to raiſe the temperature of it ten times 146 degrees, (if its capacity at ſuch a high temperature ſtill could be unvaried) or which is required to heat 1460 times as much water by one degree. Now according to our third hypotheſis, the whole quantity of heat in the water muſt be equal to the quantity of heat which would be able to raiſe the temperature of the ſame water, (ſuppoſing its capacity unvaried) as many degrees as there are between the freezing point and the point of abſolute privation of heat; or which would be able to raiſe by one degree, the temperature of as many times the quantity of water as amounts to the number of thoſe degrees. Conſequently, we may conclude, that the loweſt point of the thermometric ſcale is ſituated at the 1460th degree below the freezing point.

If ſimilar computations be made from experiments with different bodies undergoing ſudden changes in their capacities, and the diſtance of the computed loweſt point always turns out the ſame, we may ſafely conclude, that this is the very point required: we may likewiſe conclude, that in all theſe caſes, the three hypotheſes abovementioned are true.

The agreement which, as far as obſervations have been made, has been conſtantly found between the increments or decrements of the capacities, and the ſimultaneous variations of the temperatures of bodies, renders it extremely probable, that all the phenomena of heat or cold produced, originate from this cauſe; but as for the truth of the eſtimation of the abſolute quantities of heat, by calculations founded upon our third hypotheſis, we muſt own, that there are ſtill proofs wanting: ſeveral experiments having already been made in order to aſcertain the truth, when ſome of them, though made in very different circumſtances,

have

have been found to agree very nearly with each other, while in others, ſome anomalous deviations have been obſerved. But theſe experiments are of ſo very delicate a nature, and ſo newly deviſed, that all the difficulties which may give riſe to miſtakes, cannot poſſibly as yet have been removed.

One of the greateſt difficulties that we have been aware of in theſe experiments, ariſes from continual variations in the capacities of ſome bodies. Theſe render it extremely difficult to determine the real capacity of ſuch a body at a given temperature. This difficulty, however, is not inſuperable; though it will require no little circumſpection and pains to overcome it. But the object is noble, and the hope to penetrate this dark and intricate ſubject, and throws light upon it, is ſo animating, that there can be no doubt, but that Philoſophers will perſevere in the inveſtigation of it, till every doubt is cleared up, and the whole theory, which at preſent, on account of its beautiful harmony and ſimplicity, claims the preference before any other; is either ſufficiently proved, or elſe reduced to its proper limits.

A TABLE of the Capacities of Bodies, as determined by different Persons, viz.

| No. | | Dr. Crawford. | Dr. Irwine and Mr. Kirwan, as reported by Mr. Magellan. | Professor Wilcke. | M. Lavoisier. | Professor Gadolin. |
|---|---|---|---|---|---|---|
| 1 | INFLAMMABLE air from metals - | 21,400 | | | | |
| 2 | Pure air - - - - | 4,750 | | | | |
| 3 | Atmospheric air - - - | 1,790 | | | | |
| 4 | Aerated volatile alkali - - - | - | 1,851 | | | |
| 5 | Solution of brown sugar - - | - | 1,086 | | | |
| 6 | Rectified spirit of wine - - - | - | 1,086 | | | |
| 7 | Fixed air - - - - | 1,045 | | | | |
| 8 | Arterial blood - - - | 1,030 | | | | |
| 9 | Water - - - - | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| 10 | Fresh cow's milk - - - | 0,999 | | | | |
| 11 | Volatile liver of sulphur - - - | - | 0,994 | | | |
| 12 | Venous blood - - - | 0,970 | | | | |
| 13 | Common salt dissolved in 10 parts of water | - | - | - | - | 0,936 |
| 14 | Oil of vitriol diluted with 10 parts of water | - | - | - | - | 0,925 |
| 15 | Common salt dissolved in 6,4 parts of water - | - | - | - | - | 0,905 |
| 16 | Ice - - - - - | - | 0,900 | | | |
| 17 | Common salt dissolved in 5 parts of water - | - | - | - | - | 0,868 |
| 18 | Oil of vitriol mixed with 5 of do. - - | - | - | - | - | 0,876 |
| 19 | Pure nitrous acid - - - | - | 0,844 | | | |
| 20 | Epsom salt dissolved in 2 parts of water - | - | 0,844 | | | |
| 21 | Common salt——— in 8 of do. - - - | - | 0,832 | | | |
| 22 | Common salt——— in 3,33 of do. - - | - | - | - | - | 0,820 |
| 23 | Saltpetre ——— in 8 of do. - - - | - | - | | 0,8167 | |
| 24 | Common salt——— in 2,8 of do. - - | - | | - | - | 0,802 |
| 25 | Sal ammoniac —— in 1,5 of do. - - | - | 0,798 | | | |
| 26 | Common salt, a saturated solution of it in 2,69 of do. - - - | | | - | - | 0,793 |
| 27 | Mephitic gas - - - - - | 0,794 | | | | |
| 28 | Ox's hide with the hair on - - | 0,787 | | | | |
| 29 | Sheep's lungs - - - - - | 0,769 | | | | |
| 30 | Cream of tartar dissolved in 237,3 parts of water | - | 0,765 | | | |
| 31 | Oil tartari per deliquium, sp. gr. 1,346 - | - | 0,759 | | | |
| 32 | Colourless oil of vitriol do. 1,885 - | - | 0,758 | | | |
| 33 | Oil of vitriol diluted with 2 parts of water | - | - | - | - | 0,749 |
| 34 | Green vitriol dissolved in 2,5 do. - | - | 0,734 | | | |
| 35 | Glauber's salt ——— in 2,9 do. - | - | 0,728 | | | |
| 36 | Lean of beef - - - - | 0,740 | | | | |
| 37 | Olive oil - - - - - - | | 0710, | | | |
| 38 | Caustic volatile alkali sp. gr. 0,997 - - | | 0,708 | | | |
| 39 | Smoaking marine acid do. 1,122 - - | - | 0,680 | | | |
| 40 | Oil of vitriol diluted with 1,25 parts of water - | - | - | - | 0,663102 | |
| 41 | Nitrous acid ——— sp. gr. 1,29895 - - | - | - | - | 0,661391 | |
| 42 | A mixture of this acid with quicklime in the proportion of $9\frac{1}{3}$ to 1 | - | - | - | 0,61895 | |

CAPA-

CAPACITIES of receiving or communicating Heat, observed by

| | Dr. Crawford. | Mr. Kirwan, &c. | Professor Wilcke. | M. Lavoisier. | Professor Gadolin. |
|---|---|---|---|---|---|
| 43 Oil of vitriol diluted with an equal weight of water | - | - | - | - | 0,605 |
| 44 Oil of vitriol diluted with $\frac{3}{4}$ parts of water | - | - | - | 0,603162 | |
| 45 Alcohol | 0,6024 | | | | |
| 46 Smoaking nitrous acid, ſp. gr. 1,354 | - | 0,576 | | | |
| 47 Linſeed oil | - | 0,528 | | | |
| 48 Rice | 0,506 | | | | |
| 49 Horſe beans | 0,502 | | | | |
| 50 Duſt of the pine tree | 0,500 | | | | |
| 51 Oil of vitriol diluted with $\frac{1}{2}$ of water | - | - | - | - | 0,500 |
| 52 Peaſe | 0,492 | | | | |
| 53 Wheat | 0,477 | | | | |
| 54 Oil of turpentine | - | 0,472 | | | |
| 55 White wax | - | - | - | - | 0,4[illegible]0 |
| 56 Oil of vitriol diluted with $\frac{1}{4}$ part of water | - | - | - | - | 0,442 |
| 57 Water and quicklime mixed in the proportion of 9 to 16 | - | - | - | 0,439116 | |
| 58 Dark oil of vitriol, ſp. gr. 1,872 | - | 0,429 | | | |
| 59 Oats with the hulls taken off | 0,416 | | | | |
| 60 Unhulled barley | 0,421 | | | | |
| 61 Spermaceti oil | - | 0,399 | | | |
| 62 Charcoal of birch wood | | - | - | - | 0,395 |
| 63 Vinegar of unhuled red wine | - | 03,87 | | | |
| 64 Magneſia aërata | - | - | - | - | 0,379 |
| 65 Rye | 0,340 | | | | |
| 66 Concentrated colourleſs oil of vitriol | | - | - | - | 0,339 |
| 67 Oil of vitriol ſp. gr. 1,87058 | - | | - | 0,334597 | |
| 68 Pruſſian blue | - | - | - | - | 0,330 |
| 69 Quicklime ſaturated with water and dried | - | - | - | - | 0,280 |
| 70 Pit coal | 0,27777 | | | | |
| 71 Charcoal | 0,26315 | | | | |
| 72 Gypſum (artificial) | - | - | - | - | 0,264 |
| 73 Chalk | 0,256 | | | | |
| 74 Ruſt of iron | 0,250 | | | | |
| 75 Quick lime | 0,245 | | | | |
| 76 White clay | - | - | - | - | 0,241 |
| 77 Diaphoretic antimony waſhed | 0,22727 | | | | |
| 78 Calx of copper precipitated from blue vitriol, by an alkali, and the air extricated from it by nitrous acid and fire | 022727, | | | | |
| 79 Common ſalt, in cryſtals | - | - | - | - | 0,226 |
| 80 Quicklime, as it is commonly to be had | - | - | - | 0,21689 | |
| 81 Chalk | - | - | - | - | 0,207 |
| 82 Sand | 0,206 | | | | |
| 83 Agate, ſpec. grav. 2,648 | - | - | 0,195 | | |
| 84 Earthen ware | - | 0,195 | | | |
| 85 White glaſs, made without lead | - | - | - | 0,1929 | |
| 86 Cinders | 0,1923 | | | | |
| 87 White glaſs (Swediſh), ſp. gr. 2,386 | - | - | 0,187 | | |
| 88 Aſhes of pit coal | 0,18552 | | | | |
| 89 White clay, burnt | - | - | - | - | 0,185 |
| 90 Black lead | - | - | - | - | 0,183 |

CAPA-

CAPCITIES of receiwing or communicating Heat, obferved by

| | Dr. Crawford. | Mr. Kirwan, &c. | Profeffor Wilcke. | M. Lavoifier. | Profeffor Gadolin. |
|---|---|---|---|---|---|
| 91 Sulphur - - - - - | - | 0,183 | | | |
| 92 Flint glafs - - - - - | - | 0,174 | | | |
| 93 Wafhed diaphoretic antimony, from which the air had been extricated by nitrous acid and fire | 0,16666 | | | | |
| 94 Ruft of iron, from which the air had been extricated by nitrous acid and fire - - | 0,16666 | | | | |
| 95 Afhes of the elm tree - - - | 0,14025 | | | | |
| 96 Calx of zinc, from which the air had been extricated by nitrous acid and fire - - | 0,13698 | | | | |
| 97 White caft-iron (containing but little plumbago) - - - - - | - | - | - | - | 0,132 |
| 98 White calx of arfenic - - - | - | - | - | - | 0,126 |
| 99 Iron - - - - - - | 0,12696 | | | | |
| 100 Iron, fp. gr. 7,876 - - - - | - | - | 0,126 | | |
| 101 Dark-coloured caft iron, (abounding in plum-(bago - - - - - - | - | - | - | - | 0,124 |
| 102 Hardened fteel - - - - - | - | - | - | - | 0,123 |
| 103 Steel, made foft by fire - - - | - | - | - | - | 0,120 |
| 104 Soft bar iron, fp. gr. 7,724 - - - | - | - | - | - | 0,119 |
| 105 Brafs ——— fp. gr. 8,356 - - - | - | - | 0,116 | | |
| 106 Copper ——— fp. gr. 8,784 - - - | | - | 0,114 | | |
| 107 Bar iron made thin, and afterwards hammered till it grew very hot, fp. gr. 8,353 - - | - | - | - | - | 0,114 |
| 108 Brafs - - - - - - | 0,11235 | | | | |
| 109 Copper - - - - - - | 0,11111 | | | | |
| 110 Bar iron - - - - - - | - | - | - | 0,109985 | |
| 111 White calx of tin - - - - | 0,10869 | | | | |
| 112 Vinegar concentrated and diftilled - - | - | 0,103 | | | |
| 113 Zinc, fp. gr. 7,154 - - - - | - | - | 0,102 | | |
| 114 A mixture of lead and tin calcined together | - | 0,102 | | | |
| 115 White calx of tin, from which the air had been feparated by nitrous acid and fire - - | 0,099009 | | | | |
| 116 Caft pure copper, heated between charcoal, and cooled very flowly, fp. gr. 7,907 - | - | - | - | - | 0,099 |
| 117 Hammered copper, fp. gr. 9,150 - - | - | - | - | - | 0,097 |
| 118 Calx of tin - - - - - | - | 0,096 | | | |
| 119 Zinc - - - - - - | 0,09433 | | | | |
| 120 Afhes of charcoal - - - - | 0,0909 | | | | |
| 121 Sublimed regulus of arfenic - - - | - | - | - | - | 0,084 |
| 122 Silver, fpec. grav. 10,001 - - - | - | - | 0,082 | | |
| 123 Tin - - - - - - | 0,070422 | | | | |
| 124 White lead - - - - - | - | - | - | - | 0,067 |
| 125 Minium and yellow calx of lead - - | 0,06802 | | | | |
| 126 Regulus of antimony - - - - - | 0,06451 | | | | |
| 127 Antimony, fp. gr. 6,107 - - - | - | - | 0,063 | | |
| 128 Tin - - - - - - | - | - | 0,060 | | |
| 129 Minium - - - - - - | - | - | - | - | 0,059 |
| 130 Gold, fp. gr. 19,04 - - - - | - | - | 0,053 | | |
| 131 Litharge - - - - - - | - | - | - | - | 0,049 |
| 132 Bifmuth, fp. gr. 9,861 - - - | - | - | 0,043 | | |
| 133 Lead, fp. gr. 114,56 - - - | - | - | 0,042 | | |
| 134 Lead - - - - - - | 0,0352 | | | | |
| 135 Quickfilver, fp. gr. 13,3 - - - | - | 0,033 | | | |
| 136 Quickfilver - - - - - | - | - | - | 0,029 | |

SECT.

## SECT. II. Light,

The ſecond element in different ways, is fixed in various bodies, which it always renders inflammable, i. e. capable of ſhining and producing heat, by giving out again the light they have received, and with it the heat which light always introduces with itſelf on its entrance into bodies. In this ſtate, viz. combined with heat and ſenſibly gravitating matter, it is called *Phlogiſton*: with heat alone, and diſengaged from the attractive power of other ſubſtances, it is called *Fire*. The compounding together of theſe two ideas, heat and fire, and the conſequent promiſcuous uſe of the terms denoting theſe ideas, has occaſioned the greateſt perplexity, not only in Chemiſtry, but likewiſe in Natural Philoſophy in general. The action of fire is certainly very different from that of mere heat. Fire reduces the noble metals; heat only fuſes them, and by diſpoſing the phlogiſton to ſeparate from them, rather tends to calcine them. In mercury this is notoriouſly the caſe: for, with the aſſiſtance of air, the calcination of this ſubſtance is actually effected by mere heat; whereas, when the retort begins to be red-hot, i. e. when *ſome* of the rays of light only are admitted, this metal reabſorbs the light it had loſt, and is inſtantly reduced. Neither will nitre nor the black calx of maganeſe give out the pure air contained in them, in conſequence of the action of heat alone: but light muſt likewiſe be joined to the heat, that is, the veſſel muſt be red-hot, before this effect can be obtained in either ſubſtance. In the former, the light acts by attracting itſelf to the baſis of the nitrous acid and forming with it nitrous gas, which, when volatilized and carried off by the heat applied ab extra, leaves the pure air, with which it was before combined, to make its eſcape afterwards. In the caſe of the calx of maganeſe, the light operates by phlogiſticating the calx, though not abſolutely reducing it, and thus gives the air an opportunity to eſcape. For it is to be obſerved, as an invariable rule, that wherever air enters, light or phlogiſton flies off; or rather, the one cannot enter, till the other is diſpoſed to depart; and ſo vice verſâ. In this caſe (and it is the caſe of the earths of all the noble metals impregnated with air) the air is diſpoſed to fly off by the heat continually urging it upwards, and thus expelling it from the calx in which it is contained. In this manner the attraction between them being weakened, it becomes the leſs difficult for the phlogiſton or light from the fire to unite with the calx and partly reduce it.

To many other ſubſtances phlogiſton or light in its fixed ſtate is transferred by a double elective attraction: and in this way it is, that the baſe metals are reduced. The vegetable principle which forms the baſe of charcoal, having its union with phlogiſton, its other component principle, weakened by heat, attracts the air of the atmoſphere, which now quitting the metallic calx, gives this latter an opportunity of uniting with the phlogiſton of the charcoal.

So that the attraction of gold and the noble metals to phlogiſton ſeems greater than it is to air, as they need not the agency of a double decompoſition for their reduction. While, on the contrary, the calces of the baſer metals, together with the baſes of ſulphur and of moſt other combuſtible bodies, cannot have their phlogiſton reſtored to them without a double decompoſition at the ſame time taking place.

Light unites with the vegetable principle in plants, and expels pure air from them, thus converting acid and auſtere, into ſweet and emollient ſubſtances. From vegetables which grow in water, impregnated with the aerial acid, a ſtill greater quantity of air is produced, in conſequence of the union of this element with the vegetable principle. In the ſame manner, this ſubtle matter appears to decompoſe water, as well that in which plants grow, as that in which they are only immerſed, by uniting with the hydrophloge of the water, and with it forming oils, reſins, &c. containing inflammable gas.

Light acts likewiſe on the aerated muriatic acid, by phlogiſticating it, and at the ſame time expelling the air from it. In the ſame manner it phlogiſticates and deaerates the nitrous acid and the ſolutions and precipitates of ſilver, mercury, and biſmuth. In all theſe caſes, air is precipitated by light, in conſequence of theſe bodies having a greater attraction for the latter than they have for the former element. When air, on the contrary, takes the place of light, it is generally in a red heat, in other words, inflammation is neceſſary in order to expel the light or phlogiſton. This, however, is not always the caſe, as Mr. KIRWAN ſuppoſes it to be; for we find water generated in the decompoſition of alkaline gas by aerated muriatic gas: the hydrophloge of the inflammable gas contained in the volatile alkali being ſeparated from its phlogiſton and united with the pure air of the aerated acid by a double elective attraction, and the phlogiſton at the ſame time paſſing over to the acid.

The ſuppoſition that light acts in all the abovementioned proceſſes by fuſing the oxygenous principle, i. e. that it acts as heat, is equally void of foundation; as

as without having recourfe with the French academicians to an imaginary bafe, we are well affured that air itfelf is prefent in thefe fubftances, though in a very condenfed ftate: much lefs can we fuppofe that light is capable of fupplying the place of heat in melting this bafe; thefe two fluids poffeffing very diftinct, and, in fome repects, oppofite qualities.

## SECT. III. Air.

*Air*, if under this denomination we confider the atmofphere of our globe, is fo far from being an element, that it is an extremely compounded and heterogeneous body. Befides water, aerial acid and other vapours that it generally contains, there are two fluids always to be found in it, viz. refpirable air, and mephitic gas, which therefore are to be confidered as effential parts of the atmofphere. But the ufe of the word, *air*, either fingly or accompanied by the epithet *pure*, we would wifh to attach to that part of the atmofphere which fuftains animal life and flame, and without which they cannot for a moment fubfift. It is this fluid which enters into the compofition of moft bodies, efpecially of thofe from which the phlogifton or element of light has been feparated. While it does this, heat is extricated from the body; and, if the quantity of heat fo extricated be confiderable, and the heat be feparated in fuch a form as to become evident to the fenfes; the light is extricated with the heat, and the body is inflamed and burned. But it fometimes happens, that air takes the place of light and heat (or phlogifton), without caufing inflammation, or even generating much fenfible heat. In thefe cafes, the phlogifton is feparated in fome other form than that of light, viz. in that of inflammable or nitrous gas, &c. but always in combination with fome other principle or conftituent part of the body.—The other chief component part of our atmofphere, viz. mephitis or phlogifticated air, will be treated of in its place among the gafes.

Pure air, when combined with folid bodies, is in a ftate of great condenfation; as it adds confiderably to their weight without very vifibly increafing their bulk. It is attracted by water; and therefore, all water naturally contains air, and all air water. This fluid, called *vital air* by M. *Lavoifier* and which ever fince Dr. *Prieftley*'s difcovery of it, has been known under the very improper denomination of *dephlogifticated* air, is feparated in various quantities by the united action of light and heat, and fometimes of light alone, from calcined mercury, and red precipitate; from the precipitates of different mercurial falts by cauftic

alkalies, from minium moiftened with nitrous acid, from nitres with alkaline, or earthy bafes, lunar nitre, manganefe, either alone or moiftened with vitriolic acid, from the aerated marine acid, oxycrate of mercury, arfenicrate of zinc. It is likewife obtained from the leaves of plants, raw filk and other organifed fubftances, immerfed in water impregnated with the aerial acid, and expofed to the fun's rays.

Pure air is rather heavier than the air of the atmofphere. It is the only elaftic fluid capable of maintaining combuftion, and is three times as effectual as atmofpheric air in this procefs. In that of refpiration it is equally effectual.

Combined with the vegetable principle, e. g. that exifting in charcoal, with the bafe of fulphur, with that of phofphorus, with that of fugar, with mephitic gas with the earthy bafis of arfenic, it conftitutes the aerial, the vitriolic, the phofphoric, the oxaline, the nitrous, and the arfenical acids.

United to the bafe of inflammable gas, it conftitutes water; and compounded with the earths of metals, it forms metallic calces. It deprives vegetable and animal fubftances of their colour; when abforbed by unguinous oils, it thickens them, and caufes them to approach to the ftate of wax. In combination with the muriatic and acetous acid, it forms the aerated muriatic acid, and radical vinegar. Atmofpheric air contains 28 parts of this air, mixed with 72 of mephitic.

Again, if by the word *air*, be meant the fluid we breathe, this term cannot be indifferently applied, as a generical name, to every permanently elaftic fluid. If, on the contrary, by the word *air* be underftood the fluid with which we are conftantly environed, this may be applied to feveral different fubftances, and is better expreffed by the word *atmofphere*. In the following pages, therefore, we fhall confine the appellation of air folely to that part of the atmofphere which we inhale, and by which animal life is principally fupported; and which is, therefore, termed *vital air* by M. *Lavoifier*: but, in fact, it needs no fuch diftinction: for, ftrictly fpeaking, there is but one fpecies of air. Every other fluid which preferves its vaporous elafticity in the ordinary degrees of heat of our European climates and under the ufual preffure of the atmofphere, properly comes under the denomination of *gas*, a term of uncertain derivation, impofed upon thefe fluids by Van *Helmont*, the original difcoverer of feveral of them.

Theſe fluids may be diſtributed into three claſſes. The 1ſt, containing ſuch as are not of a ſaline nature. The 2d, thoſe which are of a ſaline nature. And the 3d, ſuch as are inflammable. From *air*, although, for the ſake of convenience, as having the ſame form and elaſtic property, they are here treated of under the ſame head, they all eſſentially differ in being incapable of maintaining combuſtion and reſpiration.

| CLASS I. | CLASS II. | CLASS III. |
|---|---|---|
| Genus I. Sp. 1 Mephitis | Gen. II. Aerial acid | Gen. VI. ſp. 1 Pure inflammable gas |
| Sp. 2 Nitrous gas | III. Sulphureous acid gas | Sp. 2 Hepatic gas |
| | IV. Fluor acid gas | Sp. 3 Phoſphoric gas |
| | V. Sp. 1 Muriatic acid gas | Sp. 4 Carbonaceous gas |
| | Sp. 2 Dephlogiſticated marine gas | VII. Alkaline gas |

N. B. The cretaceous (or rather aeroxyc) and mephitized inflammable gaſes are mere mixed gaſes.

GENUS I. Sp. 1. *Mephitis*, or *mephitic gas*, ſo called by M. *Lavoiſier*, from its being adverſe to the animal frame. It was formerly ſuppoſed by Dr. *Prieſtley*, its firſt diſcoverer, to be nothing more than air altered by phlogiſton, by means of what he terms phlogiſtic proceſſes; on which account he gave it the name of phlogiſticated air. But it is now aſcertained by the moſt deciſive experiments, which we owe to the penetrating genius of the Honourable Mr. *Cavendiſh*, that this fluid exiſts ready formed in the atmoſphere, and is developed in proportion as the vital or pure air is abſorbed. There are ſeveral means of procuring it in a ſtate of purity; but the proceſs uſually employed conſiſts in expoſing liver of ſulphur in the liquid ſtate, to a given quantity of atmoſpheric air under a glaſs veſſel. The liver of ſulphur abſorbs the vital air by degrees; and when the abſorption is finiſhed, the pure mephitis remain behind. It is likewiſe produced by treating muſcular fleſh, or the fibrous part of the blood well waſhed in a pneumatic apparatus: but it is neceſſary that theſe animal matters be very freſh; as otherwiſe they emit the aerial acid mixed with the mephitis. This fluid has been diſcovered likewiſe in the bladders of carp, and may eaſily be collected by breaking them under glaſs veſſels filled with water.

Mephitis is lighter than atmoſpheric air. It inſtantly extinguiſhes a lighted taper, and very quickly deprives animals plunged into it, of life. Mixed with pure air in the proportion of 72 to 28, it forms artificial atmoſpheric air. In a greater proportion it becomes noxious. Neither water, earths, nor acids have any viſible action upon this gas, yet it ſeems capable of being abſorbed by the nitrous acid, which is rendered fuming by it. Mr. *Cavendiſh* has diſcovered that 3 parts of mephitis mixed with 7 parts of vital air, and expoſed to the paſſage of the electric ſpark, is gradually condenſed, and produces the nitrous acid; an experiment of the greateſt importance, which in a great meaſure accounts for the formation of this acid in the atmoſphere. M. *Berthollet*, in decompoſing the volatile alkali, either by the nitrous acid, or by the aerated muriatic acid, or in the detonation of fulminating gold, has found that the alkali conſiſts of 5 parts of mephitis, and one of inflammable air. He has likewiſe diſcovered that animal matters contain much mephitis, and that it is the combination of this mephitis with the inflammable gas, which forms the volatile alkali obtained by the action of fire, and by putrefaction; that the plants which afford this ſame ſalt by diſtillation, owe its formation to the mephitis they contain; and that they are juſtly entitled to the name of animal plants, which ſome chemiſts have given them. M. de *Fourcroy* has ſince aſcertained, firſt, that of all animal matters the fibrous part is that which furniſhes the greateſt quantity of mephitis, by the application of the nitrous acid; ſecondly, that after putrefaction the mephitis is no longer attainable, but that a great quantity of volatile alkali is produced. Theſe very remarkable properties of mephitis are more particularly entitled to the attention of phyſicians; they throw great light on the difference between vegetable and animal matters, on the formation of volatile alkali, on putrefaction, and on the cauſe of the production of the nitrous acid by putrid animal matters. Mephitis has neither taſte nor ſmell in any ſenſible degree; it is not ſo heavy as the aërial acid, neither does it redden the tincture of litmus, nor precipitate lime from lime-water.

GEN. I. Sp. 2. *Nitrous gas* is diſengaged during the action of a great number of combuſtible bodies on the nitrous acid; more eſpecially metals, oils, mucilages, and ſpirits of wine. It extinguiſhes flame, deprives animals of life, is neither acid nor alkaline, and is not altered by pure water: with pure air it forms again the nitrous acid, becauſe it is itſelf nothing elſe than nitrous acid phlogiſticated and deprived of part of its air, and conſequently compoſed of mephitis,

phitis, phlogiſton and air, but containing more of the firſt and leſs of the laſt than the nitrous acid itſelf.

Hence ariſes the difference between the ſeveral ſpecimens of this gas, according to the proportion of mephitis and pure air which it contains; and hence the uncertainty which eudiometric experiments are liable to. It will be eaſily underſtood from theſe circumſtances, why in many caſes, and eſpecially when a body very greedy of air is employed to obtain nitrous gas, and which abſorbs much of that principle for its ſaturation, a nitrous gas is obtained, containing mephitis diſengaged, and ſometimes the product is nothing elſe but mephitis. Laſtly, it is to the ſame property of nitrous gas, that the ſingular effect of liver of ſulphur on this gas is to be attributed. A ſolution of the liver, placed under a glaſs veſſel full of nitrous gas, quickly abſorbs a part: the remainder no longer becomes acid by the contact of atmoſpheric air, but maintains combuſtion better than the air of the atmoſphere. It is, in fact, air ſomewhat more pure than common air: the proportion of vital air to mephitis is more conſiderable; but if the hepar be ſuffered to continue its action on the gas, all the vital air is abſorbed, and the reſidue is pure mephitis.

Theſe leading properties of nitrous gas, and in particular its rapid combination with pure air, indicate its analogy with combuſtible bodies; and MACQUER has obſerved, that the artificial fixation of the nitrous acid, which takes place in the mixture of theſe two gaſes, is a kind of combuſtion. But as this appearance is not accompanied with flame, it was not thought proper to rank the nitrous gas among the inflammable gaſes. However, as it abſorbs air with great eagerneſs and rapidity, a circumſtance in which it does not even yield to phoſphorus and the pyrophori, excepting that during its union with air, it does not part with any of its phlogiſton, it does not ſeem to differ from the moſt combuſtible ſubſtances. It may, therefore, in ſome meaſure, be conſidered as a nitrous ſulphur; and we have accordingly mentioned it as ſuch in its place among the ſulphurs.

GEN. II. The *aerial acid*, ſo denominated by *Bergmann*, but originally called *fixed air* by Dr. *Black*, who firſt diſcovered it in chalk, alkali, and magneſia, requires the moſt attentive conſideration. It is formed of pure air united to a baſe, which from its being found in oil, charcoal, and all vegetable ſubſtances, may be termed the *vegetable* baſis. M. *Lavoiſier*, burned a determinate quantity of charcoal over mercury in glaſs veſſels filled with pure air. The char-

charcoal was deprived of aqueous inflammable gas, by a previous calcination in close vessels, as he had observed, that without this precaution drops of water were obtained, by which the accuracy of the results were affected. The combustion began by the help of a quarter of a grain of fungus placed on the charcoal, in contact with a very small particle of phosphorus: a bent wire, whose end was heated red, being passed through the mercury, served to set the phosphorus on fire; this communicated to the fungus, and the latter to the charcoal. The inflammation was very rapid, and attended with much light. The whole apparatus being cold, M. *Lavoisier* introduced caustic fixed alkali in the fluid state, which absorbed the cretaceous acid formed during this combustion, and left a portion of vital air as pure as at the begining of the experiment. Some ashes remained, and the quantity of aerial acid formed, exceeded the weight of the vital air made use of, by a quantity equal to the loss sustained by the charcoal. From this experiment and many others it is evident that well burned charcoal consists of the common vegetable basis, a very small quantity of earth and phlogiston; and while this latter is dissipated by combustion in the form of light and heat, the vegetable principle uniting with pure air, forms the aerial acid. According to *Lavoisier*, a centenary of it consists of about twenty-eight parts of the vegetable principle and seventy-two of air.

GEN. III. *Vitriolic acid gas*, called by Dr. *Priestley vitriolic air*, and *sulphureous acid gas* by foreigners *, is formed whenever a combustible body takes away a part of the aerial principle, which is united to sulphur in the vitriolic acid. It is supposed by M. *Berthollet* to be nothing but sulphur united with a quantity of the oxygenous principle (or base of air) less than that with which it constitutes vitriolic acid †. It is a kind of middle substance between this last and sulphur; it is likewise formed when sulphur burning slowly absorbs but a small quantity of the pure air contained in the atmosphere. Vitriolic gas is very soluble in water; it destroys many vegetable colours; and, in this character, it resembles the dephlogisticated muriatic acid: so that its oxygenous principle, viz. the air,

* The shortest, and at the same time most expressive name for this aeriform substance perhaps would be *sulphoroxyc gas*.

† There are no experiments to prove the actual existence of sulphur in vitriolic acid gas. It seems more consonant to reason to say, that sulphur by uniting with a certain quantity of air, and at the same time parting with a proportionate share of its phlogiston, forms vitriolic acid gas: and on its union with more air, and giving out more of its phlogiston, constitutes vitriolic acid.

seems

ſeems to be either totally or nearly diſengaged. Vitriolic gas when united with alkaline baſes, forms neutral ſalts different from thoſe which are formed by the vitriolic acid, both in their figure, and their taſte, and more eſpecially in the property of being decompoſed by the more feeble acids, not excepting even that of vinegar. As the metals which reduce the vitriolic acid into the ſtate of ſulphureous acid gas do not effect this, but by the aſſiſtance of a certain degree of heat, it appears that this decompoſition is the conſequence of a double attraction. According to the French academicians, while the metal tends to abſorb the air from the vitriolic acid, and becomes calcined, the heat combines with the ſulphur and a portion of the air, and thus produces the vitriolic acid gas. Thus is this fact explained by M. de *Fourcroy*; but it is by no means certain, or even probable, that heat is neceſſary in order to combine with the ſulphureous principle in the formation of ſulphureous gas; on the contrary, it is much more conſonant to reaſon to ſuppoſe, that it is the phlogiſton of the metal which combining with the *baſe* of ſulphur and part of the air, forms ſulphureous or vitriolic acid gas: to which the heat contributes no otherwiſe than as it inſtantaneouſly diſengages the phlogiſton from the metallic baſe, which when the decompoſition is made without heat, as in the inſtance of the generation of inflammable gas from metals by water, requires a length of time.

GEN. IV. The *fluor*, or *fluoroxyc*, or *ſparry acid gas*, is obtained from fluor or vitreous ſpar, by means of the vitriolic acid. The characteriſtic property of the ſparry acid, is to diſſolve and volatilize in its elaſtic ſtate, the quartzoſe earth which it ſeizes from glaſs veſſels. With alkaline baſes it forms ſalts, totally different from thoſe of the other acids; and it has not yet been determined that it is a modification either of the vitriolic, or of the muriatic acid; though ſeveral chemiſts have maintained this opinion. Its principles are not known, more particularly its baſe; but the preſence of the oxygenous principle or air, is admitted in this as well as in all the other acids.

GEN. V. Sp. 1. The *muriatic acid gas*, or rather *murioxyc gas*, or the marine acid air of Dr. *Prieſtley*, is eaſily obtained, by heating ſpirit of ſalt, or liquid muriatic acid in a retort, the neck of which is plunged beneath a veſſel filled with mercury. It may, likewiſe, be obtained in the ſame apparatus, by heating a mixture of common ſalt and oil of vitriol. This elaſtic fluid has a ſtrong and penetrating ſmell. It extinguiſhes candles, deſtroys the life of animals, reddens blue

blue vegetable colours, abſorbs the vapors of water which float in the air, and forms with them a white fume. In liquid water it becomes diſſolved, and loſes that heat which maintained its elaſtic ſtate. It cauſes ice to melt with great rapidity, by reaſon of the heat it gives out the inſtant of its combination with water. It is abſorbed by charcoal and by ſpunge; unites with all the alkaline baſes, and forms muriatic ſalts, and diſſolves camphor. The nature of this air is not yet well known; neither has any one yet ſucceeded in ſeparating the air or oxygenous principle from its baſe.

GEN. V. SP. 2. The *aerated muriatic gas**, or dephlogiſticated marine acid, is obtained with great facility during the mutual action of the native calx of manganeſe, and the muriatic acid. According to the French academicians, this production of a peculiar gas is due to the tranſition of the baſe of the pure air †, or oxygenous principle of the calx of manganeſe into the muriatic acid: but as the calx at the ſame time certainly gains phlogiſton, the dephlogiſtication of the acid muſt likewiſe be taken into the account.

This gas has always a yellow greeniſh colour, with a ſtrong and penetrating ſmell. It is not acid, extinguiſhes flame, and quickly deſtroys animal life; it deſtroys alſo the colours of dyed ſtuffs, the tincture of turnſole, ſyrup of violets, and vegetables, by reducing them to a white. It takes the colour from, and even blanches yellow wax, &c. It decompoſes the volatile alkali, which may, therefore, be uſed as a preſervative againſt its noxious effects; it ſeparates the mephitis, in proportion as the pure air of the muriatic gas unites with the hydrophloge of the volatile alkali, with which it forms water. It thickens unguinous oils, calcines metals, not excepting mercury and gold, and diſſolves in water, to which it communicates all theſe properties. The contact of light gradually decompoſes it, and reduces it to the ſtate of pure muriatic acid.

* Or, more briefly and elegantly, the *epimuriatic gas.*

† This gas then conſiſts in fact of muriatic acid gas (or murioxyc gas) which has been deprived of its phlogiſton, and ſaturated with pure air: for the baſe of pure air, as we have endeavoured to ſhew above, is as faulty an expreſſion as the oxygenous principle; as otherwiſe every body, which receives an acceſſion of heat ſufficient to form it into a gas or permanent vapor, might be conſidered as being moſtly the baſe of that gas. Thus ordinary vapor, which is water, united with a certain quantity of the matter of heat, might be conſidered as a peculiar ſubſtance, of which water was the baſe. The ſame may be ſaid of the fumes of ſulphur, and the vapors of moſt other ſolid and liquid bodies.

GEN.

GEN. VI. SP. I. *Pure inflammable gas*, commonly called *inflammable air*, is the lighteſt of all the aeriform fluids. When it is very pure, it is thirteen times lighter than atmoſpheric air; extinguiſhes fire; kills animals; takes fire if vital air be preſent, by the contact of the electric ſpark, or of any combuſtible body already in a ſtate of ignition; and burns with a brilliant flame. Fourteen parts of this gas in weight abſorb eighty-ſix of vital air, during their complete combuſtion; and very pure water is formed, provided theſe two fluids themſelves be in a ſtate of purity. Inflammable gas is generally formed from this liquid by a double affinity. Thus it is that iron, zinc, charcoal and oils decompoſe water, and form this gas, by attracting the pure air of the water, at the ſame time that the phlogiſton contained in them is attracted by the hydrophlogic principle of that liquid *, with which it flies off in the form of an inflammable elaſtic fluid †. The leaves of vegetables, on the contrary, poſſeſs the property of abſorbing the hydrophloge of water, and permitting the oxygenous principle to become diſengaged in the ſtate of pure air. Inflammable gas combined with mephitis, conſtitutes the volatile alkali. This compoſition has been analytically demonſtrated by M. *Berthollet*, who has ſince ſucceeded likewiſe in compoſing the volatile alkali by the direct union of theſe two bodies. The heat contained in inflammable gas, has not yet been ſeparated, except in ſuch caſes as when this body enters into a compound ſtate. The preſſure and the degree of cold neceſſary to effect this ſeparation are not yet in our power; and every experiment ſerves to ſhew that both the one and the other muſt be in the extreme to produce this effect. In the opinion of ſome, it is to the ſudden diſengagement and rapid inflammation of this gas, that all the fulminations and detonations obſerved in chemiſtry are to be attributed. However this may be, it is certain that the inſtantaneous recompoſition of water is very often the reſult of theſe detonations.

* Oils contain in themſelves a large quantity of hydrophloge.

† In the view we have here given of the formation of this fluid, the difficulty contained in the dilemma, with which M. *Kirwan*, in his *Eſſay on Phlogiſton*, p. 97, urges Meſſrs. *Lavoiſier* and *de la Place*, who conſider it as a ſimple ſubſtance, is certainly overcome. " Every decompoſition, ſays he, ariſes either from a ſingle or double affinity: yet neither can here be ſaid to take place. Not a double affinity; ſince the inflammable air eſcapes without uniting with the acid. Not a ſingle affinity; ſince there is no proof that any ſuch exiſts in this caſe; and, if it did exiſt, water ſhould be as eaſily decompoſed by iron without an acid as when an acid is preſent, or rather more eaſily, becauſe of the affinity of the water to the acid." This latter objection, indeed, ſeems equally to militate againſt the theory given above: but it ſhould be conſidered that the acid more than compenſates for this circumſtance, by the attraction it exerts on the earth of the iron, by which means the phlogiſton, being looſened, can the more readily combine with the hydrophloge, and form inflammable air.

Gen. VI. Sp. 2. *Hepatic gas* has been very properly diſtinguiſhed from the other inflammable gaſes by *Bergmann*. It is obtained from livers of ſulphur, or ſolid hepars, decompoſed by means of acids in the pneumatic apparatus. This aeriform fluid has a fetid odour. It kills animals, and turns ſyrup of violets green. Vital air precipitates the ſulphur. It takes fire by the electric ſpark, and by the contact of inflamed bodies, burning with a reddiſh blue flame, ſulphur being at the ſame time depoſited on the ſides of the veſſels. The ſmoaking nitrous acid, and the ſulphureous acid, decompoſe or deſtroy its elaſtic fluidity, and ſeparate the ſulphur. This gas unites with water; but the ſolution is decompoſed by expoſure to the air, and by the ſame acids as decompoſe the gas itſelf. Hepatic gas gives a deeper colour to the calces of lead and biſmuth, and even reduces them. It precipitates muriatic ſolutions. Some metals, and in particular mercury and ſilver, ſeparate the ſulphur, ſo that it cannot be transferred in veſſels over mercury without a great part of it being decompoſed. All theſe phenomena ſhew that this gas contains ſulphur in a ſtate of extreme diviſion. M. *Gengembre*, who has analyzed it, thinks it conſiſts of pure or aqueous inflammable gas and ſulphur. But the experiments of the immortal *Scheele**, the diſcoveror of this gas, plainly evince, that it is the hydrophlogium or aqueous baſe only of inflammable gas, which enters into its compoſition. Indeed, not only *Scheele*, but M. *Gengembre* himſelf, has endeavoured in vain to compoſe this gas from inflammable gas and ſulphur: and if M. *Gengembre* had not been blinded by the theory he has adopted, he would have acknowledged with *Scheele*, that this operation failed from a redundance of phlogiſton. It is this gas which mineralizes the ſulphureous or hepatic waters. The ordinary acids do not precipitate the ſulphur; but the fuming nitrous acid, and the ſulphureous acid, in which the oxygenous principle or air is not ſtrongly adherent, ſeparate the ſulphur, while they abſorb the inflammable air. The knowledge of hepatic gas explains many difficulties relating to the nature of ſulphur. Firſt, we know why the ſolid hepar has ſcarcely any ſmell, and why it emits ſo ſtrong a ſmell when it is moiſtened. Secondly, it appears that water, which ſulphur alone is incapable of decompoſing, is eaſily ſeparated into its principles, by the double action of ſulphur and alkaline matters. Thirdly, the decompoſition of livers of ſulphur by expoſure to air, and by many metallic calces, which are incapable of decompoſing water, is eaſily underſtood. Fourthly, the theory of the for-

* Vid. *Scheele's Obſervations and Experiments on Air and Fire*, tranſlated by Dr. *Forſter*, pag. 186, and ſeq.

mation

mation of ſulphureous mineral waters may be readily explained, as well as the hiſtory of their decompoſition.

GEN. VI. SP. 3. *Phoſphoric gas* was diſcovered by M. *Gengembre*; he obtained it by boiling a ſolution of cauſtic vegetable alkali with half its weight of phoſphorus, and receiving the elaſtic fluid, which is diſengaged under glaſs veſſels filled with mercury. This gas is very fetid, deſtroys animal life, takes fire ſpontaneouſly by the contact of air, and with a ſlight exploſion. The ſolid phoſphoric acid, which it affords by burning, forms a kind of crown in a ſtill air, which increaſes in diameter as it riſes. When vital air is mixed with this air under glaſs veſſels, it burns with great rapidity, producing ſo conſiderable a quantity of heat, and conſequently dilatation, that the glaſſes are ſhattered to pieces, unleſs they be very thick. M. *Gengembre* conſiders this new gas as a ſolution of phoſphorus in inflammable gas. It is rather a ſolution of phoſphorus in hydrophloge, or the aqueous baſe of this gas. It greatly reſembles hepatic gas, from which it differs only in the nature of the combuſtible body ſuſpended in the inflammable gas. As phoſphorus is much more combuſtible than ſulphur, phoſphoric gas takes fire in the air; hepatic gas, on the contrary, does not take fire, but by the contact of ſome body in ignition; and part of the ſulphur, for want of a ſufficient heat, ſeparates without burning. The hydrophloge, indeed, does not burn in either of theſe gaſes; but uniting with the pure air of the atmoſphere, forms water.

GEN. VI. SP. 4. *Carbonaceous inflammable gas.* It is now known, that charcoal, though very fixed in cloſed veſſels, and in our ordinary fires, is capable of being reduced into vapors, by means of a very high temperature; and that it is likewiſe ſoluble in elaſtic fluids. Inflammable gas, more eſpecially, has the property of diſſolving this ſubſtance, and of holding it ſuſpended; it is often, therefore, taken up by this fluid, at the time of its aſſuming the elaſtic form. This fluid burns with a blue flame, attended with ſmall white or reddiſh ſparkles. Theſe three laſt ſpecies of inflammable gaſes appear to be formed by the attraction of the hydrophlogic principle to the phlogiſton of the body held in ſolution by it, in a manner ſomewhat ſimilar to the generation of liver of ſulphur.

GEN. VII. *Alkaline gas*, diſcovered by Dr. *Prieſtley*, and conſiſting of inflammable gas united with mephitis, is rapidly decompoſed by the contact of

 the

the aerated muriatic acid, the decompoſition being attended with heat. Water charged with the muriatic acid is formed, and the aeriform mephitis remains behind. The water proceeds from the union of the baſe of the inflammable gas with the pure air of the acid, which laſt ſubſtance is at the ſame time phlogiſticated by the phlogiſton, the other principle of the inflammable gas. The decompoſition of ammoniacal copper, and of fulminating gold, which produce water by means of the action of fire; the reduction of the metal, and the mephitis obtained, ſtill further prove that the volatile alkali is compoſed of the principles here mentioned. In fact, the hydrophloge or baſe of the inflammable gas contained in the alkali, operating in this caſe by a double decompoſition, takes the pure air from the calces of the copper and gold, its ſuperfluous phlogiſton at the ſame time being diſſipated in a ſudden flaſh of light, but the far greater part combining with the metal, and leaving the mephitis at liberty. The calces of zinc, and of iron, which decompoſe water in their metallic ſtate, do not decompoſe the volatile alkali in the ſame manner; becauſe theſe metals have a ſtronger attraction to pure air than they have to phlogiſton.

The name of *mephitized inflammable gas* is given by M. *de Fourcroy* to the aeriform fluid which conſiſts of pure inflammable gas and mephitis. It is the ſame as that which was called the inflammable air of marſhes, by M. *Volta*; and is produced by the putrefaction of certain vegetable matters, and of almoſt all animal ſubſtances. It is diſengaged from ſtanding waters, and in all places where animal matters putrefy in water. It accompanies, precedes, or follows the formation of volatile alkali, which takes place in putrefaction. M. *de Fourcroy* juſtly ſuſpects this gas to be formed of the two gaſes abovementioned by mechanical mixture only. It burns with a blue flame; and does not detonate with vital air, without difficulty. After detonation in the eudiometer of M. *Volta*, ſome drops of water are found, and a reſidue of mephitis more or leſs pure.

The mixture of pure inflammable gas and aerial acid may be properly diſtinguiſhed by the epithet of *aerial acid*, or rather *aeroxyc, inflammable gas*. It is obtained by diſtillation, from many vegetable matters, and in particular from tartar, and all the tartareous ſalts, or from the acetous ſalts; from hard woods, or charcoal which is burned by the aſſiſtance of water; from pit-coal, &c. It burns with difficulty; but the cretaceous acid may compoſe three fourths of its volume without its ceaſing to be combuſtible. This acid may be ſeparated by means of lime-water, or cauſtic alkalies. It is a ſimple mixture without combination.

A TABLE

A TABLE of the abſolute Weight of 100 Cubic Inches of different kinds of Air, (or Gas) and their proportion to common Air and Water.
(*Taken from* Kirwan, *on Phlogiſton, and the* Monthly Review.)

| 100 Cubic Inches, | Grains. | Proportion to common Air. | Proportion to Water at 1000. |
|---|---|---|---|
| Atmoſpheric air | 31 | 1000 | 1,224 |
| Pure air | 34 | 1103 | 1,345 |
| Mephitis | 30,535 | 985 | 1,206 |
| Nitrous gas | 37 | 1194 | 1,462 |
| Sulphuroxyc gas | 70,215 | 2265 | 2,773 |
| Aerial acid | 46,5 | 1500 | 1,833 |
| Hepatic gas | 34,286 | 1106 | 1,353 |
| Alkaline gas | 18,16 | 600 | 721 |
| Inflammable gas | 2,613 | 84,3 | 103 |

## SECT. IV. WATER.

*Water*, from the earlieſt ages of Philoſophy, has ever been reckoned among the elements. But within theſe few years, Philoſophers have been induced by the celebrated experiments of Mr. *Cavendiſh*, (in which inflammable gas being fired in conjunction with pure air, both diſappear and leave nothing but water behind,) to conſider it as a compound. With reſpect to its component parts indeed, there are a great diverſity of opinions. That of M. *Lavoiſier*, however, is the moſt generally received. This ſuppoſes water to be compoſed of inflammable gas and the baſe of pure air. But there is no neceſſity for ſuppoſing pure air to be a compound: and, indeed, it is only nominally ſo in M. *Lavoiſier's* own ſyſtem: for, when he aſſerts that air is compoſed of a certain baſe, which he calls the oxygene principle, and the matter of heat, he ſays no more than that air in its ſeparation from the ſolid or liquid bodies with which it was united, aſſumes an additional quantity of the matter of heat, ſo as to be enabled to appear under the form of an elaſtic fluid, i. e. under the form in which we find it in the atmoſphere. But as this additional heat, both here and in the reſt of the elaſtic fluids, affects the form only, but not the nature and attractive powers of the body into which it enters, it is evident that it ought not to be reckoned one of the principles of that body.——As to the inflammable gas, which M. *Lavoiſier* ſeems to conſider as a ſimple ſubſtance, it is inconceivable how water, which is abſolutely incombuſtible, ſhould have ſo combuſtible a body as inflammable gas is, for one of its component parts. Whereas by admitting pure air in its whole ſubſtance to be one of the component parts of water, and the other to conſiſt of the baſe only of inflammable gas, which being burned by the paſſage of the electric ſpark through it, its phlogiſton is converted into light and heat, the whole doctrine of the generation of water becomes plain and eaſy, and is beſides analogous to the conſtant tenor of Nature in the transformation of other combuſtible bodies by means of air. Thus, as the baſe of ſulphur with phlogiſton forms ſulphur, and with air vitriolic acid; and as mephitis with phlogiſton forms nitrous gas, and with air, nitrous acid; again in the caſe of the metals, as the white calx of arſenic forms regulus of arſenic, and with air, arſenical acid, ſo the baſe of inflammable gas with phlogiſton forms inflammable gas, and with air, water, which like the acids abovementioned, is an incombuſtible

 body,

body, and like thefe too, when pure and unmixed with other matters, is liquid in the ordinary temperature of our climates. That it has not like them, tafte or cafticity, muft depend on the different nature of its bafe. As the name of *hydrogene* is equivocal, and might lead to notable error and mifapprehenfions, we fhall beg leave to impofe upon this principle the name of *hydrophlogium*, a name expreffive of the two fubftances formed by it in different circumftances of combination.

In the experiment here alluded to, heat is generated, not on account of the pure air giving it out in its condenfation into water: (for that the quantity* of heat extricated by this means is very fmall, the analogy of other fubftances in fimilar circumftances perfuades us): but chiefly, and almoft entirely, in confequence of the phlogifton being liberated, and making its efcape in the form of light and fenfible heat.

Water, like all other bodies, is fufceptible of the three different ftates of aggregation, folidity, fluidity, and vapor. When it paffes to the folid ftate, and becomes ice, it produces a heat of fome degrees, as indicated by the thermometer. When it is converted into vapor, it abforbs heat, and produces cold: though not to that degree, as do alcohol, æther, and fome other more volatile fubftances. It perfectly diffolves in air, in which when the thermometer ftands at 65 degrees, and the atmofphere is tolerably dry, it is invifible. In contrary circumftances it forms a whitifh opake cloud. It increafes flame in confequence of being itfelf decompofed, and giving out pure air. At fome degrees above the freezing point the vapor of water is condenfed,

* We may here fee a flagrant inftance of the impropriety of beftowing unconditionally, and without reftriction, the title of the oxygenous principle upon air; as, in this cafe, inftead of forming an acid, nearly the moft fapid and cauftic of all fubftances, it generates water, which is one of the moft mild and infipid. The muriatic acid and calces of metals have likewife been adduced by the judicious tranflator of the fecond edition of *Fourcroy*, as objections to the exiftence of an oxygenous principle: and in fact it fhould feem, that a certain portion of the phlogifton is neceffary as well as air for the formation of acids: the metals which part eafily with all their phlogifton not being convertible into acids, whereas arfenic, which obftinately retains this principle, is acidified with the greateft eafe. The fame explication may be given of the muriatic acid, which lofes its acidity by receiving an excefs of what is termed the oxygene principle, probably becaufe the action of the phlogifton it contains, vid. *Effay on Fire*, (page 70), is impeded by this excefs. In fhort, it feems that, ftrictly fpeaking, there is no fuch thing as an oxygenous principle; but that the acid faculty proceeds from a due proportion between the conftituent parts: though it is certain that air has a great fhare in this effect.

Water may be decompoſed in ſeveral ways. Firſt, by letting it ſtand upon iron filings, or, which is a ſtill ſhorter proceſs, by letting it paſs, drop by drop, through a gun barrel, &c. placed in a furnace, and kept in a red heat. The water in a ſtate of vapor is decompoſed by the contact of the iron; the pure air it contains becomes fixed in the iron, as is proved by the augmentation of the weight of this latter ſubſtance, and the ſingular alteration it undergoes. Its baſe, uniting with the phlogiſton of the metal, with which it forms inflammable gas, paſſes ſwiftly through the gun barrel, and is received in inverted glaſſes, properly adapted, at the other end. In the ſame manner, water may be decompoſed by zinc, charcoal, and oils: but the oil muſt be boiling hot, and the metal and charcoal ignited.

M. *Lavoiſier* thinks that this fluid is compoſed of ſix parts of pure air, and one of inflammable gas (or rather of hydrophlogium, the baſe of inflammable gas); that water is recompoſed by burning theſe two kinds of air together, which, if carefully performed, affords a quantity equal in weight to that of the two fluids made uſe of: and that water is thus produced in a great number of chemical operations; as for example, when ſpirit of wine or oils are burned under a chimney adapted to the worm-pipe of a ſtill, whoſe other extremity is adapted to a recipient, a quantity of water is collected, which is almoſt always greater than that of the inflammable fluid made uſe of, which is occaſioned by the baſe of the inflammable gas of theſe liquids combining with the pure air of the atmoſphere, by which their combuſtion is maintained.

It is certain then that water is not a ſimple body, but is capable of decompoſition; and it is highly probable that Nature in her great operations effects this more eaſily, and by various other proceſſes as well as thoſe diſcovered by art. It is by a decompoſition of this kind that water tends to purify the atmoſphere, by emitting pure air; that large quantities of inflammable air are diſengaged from ſtagnant waters: that the atmoſphere is ſometimes ſo highly charged with this laſt as to take fire and exhibit luminous meteors, and that water contributes to the production of ſaline matters in which pure air is always a principle.

Water has not the leaſt attraction for phlogiſton. Not only does it refuſe to enter into any union with unguinous oils and fat, reſins, and ſulphur, but it will not even unite with inflammable gas, although one of the two principles of which it conſiſts, be common to it and this fluid. It unites but imperfectly with ſoaps, hepars, and eſſential oils, ſcarcely at all with æther; but perfectly with vinous

ſpirit: and ſeems to exerciſe this ſolvent power according to the proportion ſubſiſting between the phlogiſton and the ſaline matter contained in theſe ſubſtances. It is the proper menſtruum of ſalts; and enters into union with cauſtic earths, i. e. earths of a cauſtic taſte, as lime and barytes. It likewiſe diſſolves gums and mucilages.

## SECT. V. EARTHS.

There is no ſuch element as earth, nay more, taken in a chemical ſenſe, there is no ſuch ſubſtance in nature. The word, earth, like metals, ſalts, &c. is merely a generic term, comprehending ſeveral different ſubſtances, agreeing in certain qualities, or rather, in the want of certain qualities: for the definition of earth is merely negative. " Every body that remains ſolid in the higheſt temperature of the atmoſphere, that is unfuſible in a red heat, and cannot be volatalized without great difficulty, that is inſipid, incombuſtible, and inſoluble in a thouſand times its weight of water, and is incapable of being converted into a metal by the addition of combuſtible matter, is called an *earth*." In ſhort, any ſubſtance which cannot be ranked under any of the grand diviſions of Nature, is an earth. The word earth then denotes an idea purely metaphyſical, comprehending the ſimple ideas of fixedneſs, unfuſibility, inſolubility, &c. Water and air are real entities: becauſe, when pure, they are always the ſame. But earths, like ſalts, metals, and combuſtibles, differ greatly from each other. It is a common expreſſion " a reſiduum of earth was left behind." Yet we do not ſay " a reſiduum of metal," but of metallic matter, nor " a reſiduum of ſalt;" but of ſaline matter. It ſeems, therefore, in this caſe, that a falſe hypotheſis has introduced a fallacious language; and that the language in its turn has ſerved to cover and confirm the fallacy of the hypotheſis.

The calces of metals differ from earths in general, inaſmuch as they are reducible to a metallic ſtate by the addition of phlogiſton; and from lime in particular, as well in this as in many other points: the name of earth therefore is very abſurdly beſtowed upon them: yet as lime, and theſe metallic calces (that always and theſe frequently) are acquired by means of combuſtion, there ſeems to be no great impropriety in giving them the appellation of *limes* or calces, at leaſt, the appellation is leſs improper than that of *oxids*, a term derived from a falſe, or, at beſt, from a ſuſpected hypotheſis.

There are five ſimple earths, ſimple at leaſt with reſpect to the preſent ſtate of our knowledge. One indeed, viz. barytes, has incurred the ſuſpicion of being compounded: its conſtituent parts, as far as analogy leads us, appearing to be lime and the calx of ſome metal. Theſe earths are denominated as follows: *lime**, *barytes* or heavy earth, *murioecite* or earth of magneſia †, *alumite* or earth of alum, *ſilicite* or earth of flint.

The firſt of theſe earths, called pure calcareous earth or *Lime*, has an acrid and urinous taſte, and is of a very cauſtic nature. It changes the colour of ſyrup of violets to a much deeper green than is produced by either of the two following earths. Expoſed to a very violent heat, it ſuffers no alteration. The action of water on this earth is very powerful. When a ſmall quantity of it is poured on lime, it is quickly abſorbed, the lime appearing dry as before; after a ſhort interval the lime burſts and falls to pieces; producing a degree of heat ſufficient to reduce the water into vapors, with a remarkable hiſſing noiſe. When it has abſorbed as much water as it can combine with and remain dry, it is called dry ſlaked lime; and it then no longer produces heat by the addition of water. If a large quantity of this fluid be added, the lime is perfectly diſſolved, and the liquor becomes tranſparent, and is known by the name of lime water.

With the aerial acid this earth loſes it cauſticity, and forms chalk. With ſiliceous earth it combines either in the humid or dry way. In the former it conſtitutes mortar. It likewiſe unites with clay, as alſo with murioecia, and equal parts of ſiliceous earth, murioecia and lime melt by heat into a perfect glaſs. It diſſolves in 600, or, according to others, in 680 times its weight of water, and is one of the two ſaline earths.

Beſides the properties abovementioned, the following are the characteriſtics of this earth. 1. Diſſolved in nitrous acid, and afterwards evaporated and calcined, this earth forms the *phoſphorus of Balduin*, which has the property of ſhining in

* In Latin, *calx*, *barytes*, *murioecites*, *alumites*, *ſilicites*.

† We have exchanged the very improper term, *magneſia*, for one, which in the modern way, at leaſt of pronouncing Latin in moſt parts of Europe, has nearly a ſimilar ſounding; viz. Murioecia (from muria and οικος domus) in conſequence of which circumſtance, it may, perhaps, be the more readily adopted. The name of *magneſia* may then remain with the ſubſtance on which it was originally, and with propriety, impoſed, viz. the black calx of mangeneſe, or *Cawk*, in German, *Braunſtein*; and the word *magneſium* will be as aptly applied to denote the regulus or metal extracted from this ore. But murioecia, being here ſubſtituted for *magneſia alba*, ſignifies this earth united with the aerial acid: and, conſequently, *murioecites* will denote the pure earth alone, or, what is uſually called, calcined magneſia.

the dark, after being expoſed to the light. 2. Calcined with ſulphur, it conſtitutes the ſubſtance called *Canton's phoſphorus*. 3. The marine acid cannot be ſeparated from it with the moſt violent fire. 4. It cannot be precipitated from its ſolutions in acids by cauſtic volatile alkali. 5. With vitriolic acid it forms ſelenite, an earthy ſalt ſoluble only in a large quantity of water. 6. The ſame ſalt is likewiſe generated by adding vitriolic acid, vitriolated tartar, or Glauber's ſalt, to a ſolution of this earth in the nitrous or marine acids.

Lime conſtitutes the principal part of common lime-ſtone, marble and chalk, of egg-ſhells, mother of pearl, oyſters, and muſcle-ſhells, of corals, and the ſubſtance called crabs-eyes. It alſo forms the greateſt part of the common arable lands: and is the principal baſis of vegetable and animal ſubſtances. It is very ſeldom, however, found perfectly pure in Nature.

The next of the ſaline earths is *Barytes* or ponderous earth. This, however, requires 900 times its weight of water to diſſolve it. Water thus ſaturated, gives a ſable green colour to the tincture of violets. This ſolution, like lime-water, 1. when expoſed to the air, becomes covered with a thin pellicle, which conſiſts of barytes united with the aerial acid. 2. The dry earth itſelf alſo combines, though very ſlowly, with the aerial acid exiſting in the atmoſphere. 3. Like lime too, it becomes cauſtic by fire. 4. It likewiſe imparts cauſticity to alkaline ſalts. 5. Like lime, it precipitates corroſive ſublimate of a yellow colour, and mercurius dulcis black. 6. It alſo retains obſtinately the marine acid when ſubmitted to diſtillation. 7. Neither can it be precipitated by volatile alkali, from its ſolutions in acids.

The agreement of theſe two earths in ſo many points, renders it highly probable that, if ever the latter of them ſhould be found to be of a metallic nature, it will prove to be a compound, conſiſting for the greater part of calcareous earth. The properties in which barytes differs from calcareous earth are the following: 1. with vitrolic acid it forms heavy ſpar. 2. With the nitrous and marine acids it forms ſolid non-deliqueſcent cryſtals. 3. With the acetous, a deliqueſcent compound like gum. 4. With the acids of fluor and tartar it forms much more ſoluble ſalts than lime does. 5. It decompoſes vitriolated tartar, by uniting with the acid part of this ſalt, and forming with it heavy ſpar.

This earth is chiefly found in native heavy ſpar; and is likewiſe contained in manganeſe and the aſhes of vegetables. It is to be met with united to the aerial acid only; but never in a ſtate of perfect purity.

The third earth, *Murioecite* *, requires above 7000 times its weight of water to diſſolve it in the ordinary temperature of the atmoſphere. It imparts a faint green colour to the tincture of violets, and changes that of turnſole to a blue. It does not melt in the moſt violent heat, but becomes contracted in its dimenſions. It is diſtinguiſhed by the following properties: 1. It is not rendered cauſtic by combuſtion; though in this operation it loſes from two-thirds to three-fourths of its weight. 2. The ſolution of it in marine acid, evaporated to dryneſs, and afterwards urged with a briſk fire, parts with its acid: the contrary of which is the caſe with calcareous earth. 3. The ſolution of it in nitrous acid being cryſtallized, produces a ſalt reſembling ſaltpetre, which detonates in contact with live coals; but is very deliqueſcent. 4. A paper ſteeped in this latter ſolution and dried, burns with a green flame. 5. With vitriolic acid this earth forms the ſal catharticus amarus, a ſalt remarkable for its bitter taſte: while, on the other hand, the common calcareous earth yields with the ſame acid a taſteleſs ſelenite. 6. This earth diſſolves with greater difficulty in acids after than before calcination. That this earth occurs in great abundance in Nature, is evident from the conſideration that it is contained in all ſalt ſprings, and in the mother-water of nitre; and it particularly abounds in the mineral waters of Epſom, and in ſea-water. It is moſt advantageouſly obtained from the ſal catharticus ariſing from theſe ſources. It conſtitutes the chief and diſtinguiſhing part of ſtones and earths of the ſteatitic kind; and is, conſequently, found in ſerpentine ſtone, lapis nephriticus, lapis ollaris, amianth, talc, and others of this claſs. M. *Monnet* has likewiſe diſcovered it in ſchiſti, peat, and in the different kinds of marle. It occurs alſo in common mould. But as far as it is hitherto known, it has not yet been found native in a pure and unmixed ſtate.

The fourth primitive earth, viz. *Alumite*, argillaceous earth, or earth of alum, is diſtinguiſhed by the following characters: 1. It cannot be made into lime by combuſtion. 2. Diſſolved either in the nitrous or marine acid, and urged by fire, it parts with the acid. 3. With vitriolic acid it forms a ſolution of an aſtringent aluminous taſte, from which, after evaporation, and with the addition of a little acid, genuine alum may be obtained by cryſtallization. This ſpecies of earth forms a conſiderable conſtituent part of clay and of ſchiſti. But ſand likewiſe flints, rock cryſtals, as alſo the greater number of gems and precious ſtones, contain a portion of this earth, and, in all probability, it is to be found in many

* Commonly called pure or calcined magneſia.

other

other mixed kinds of earths and ftones. It is moft conveniently and eafily extracted from alum.

The fifth and laft of the fimple earths is *Silicite*, which is diftinguifhed by the following properties: 1. When heated alone, it remains unchanged by the ftrongeft fire that can be raifed with the affiftance of the common air of the atmofphere. 2. It refifts the action of all the acids, not being foluble in any but the fluor or phofphoric acid. 3. With the addition of a fmall quantity of fixed alkali it melts to a glafs: and fufed with a ftill larger portion, it becomes foluble in water.

This earth makes the principal conftituent part of quartz, flint, and fand; chert, jafper, feldt-fpar, garnet, fhorl, bafaltes, rag-ftone, grit and pumice-ftone. It likewife enters largely into the compofition of the precious ftones of the firft order, fuch as ruby, topaz, hyacinth, &c. and of the fecond, as agate, onyx, cornelian. It occurs almoft pure in rock-cryftal: but is not to be had in a ftate of abfolute purity, otherwife than by precipitation from clear quartz, and other fubftances containing it, by means of an acid. For this purpofe thefe fubftances muft be previoufly fufed with four times their quantity of fixed alkali, and diffolved in water.

## SECT. VI. SALTS.

*Salts* are bodies, which, when reduced to a fine powder, are foluble in a thoufand times their weight of boiling water.

N. B. The fpecific gravity of thefe fubftances with refpect to water, feldom exceeds the ratio of two to one. *Bergmann.* N. Act. Upfal. Tom. IV, pag. 75. Etiam Opufc, Vol. IV.

Salts are divided into *fimple* and *compound*.

*Simple* falts are either *acids*, or *alkalies*.

*Acids* are known by their tafte, and by their reddening moft of the blue and violet-coloured juices of vegetables.

Moft of the mineral acids have been formed from combuftibles, which have received pure air, and parted with their phlogifton, either by means of combuftion, or of a double elective attraction.

4 The

The nitrous acid, indeed, does not ſeem properly to originate from either of theſe cauſes, the two principles of which it is compoſed being abſolutely incombuſtible. But nitrous gas attracts air by a proceſs ſimilar to combuſtion, and with it forms phlogiſticated nitrous acid, which is capable of receiving more air at the ſame time that it parts with its phlogiſton, by a double elective attraction: thus forming the pure dephlogiſticated nitrous acid. Of the origin of the muriatic, boracic, and fluor acids, we know nothing.

*Alkalies* have an acid urinous taſte, change the colour of moſt of the blue and violet-coloured juices of vegetables to a green, and attract water from the air, ſufficient for their ſolution*.

Theſe are but three in number. Two fixed, and one volatile. The firſt in the order of attraction to acids is called the *vegetable* fixed alkali, or *ſpodium*†. The ſecond, the *mineral* fixed alkali, or *natrum*. The third and laſt, the *volatile* alkali, or *ammonium*.

The *Compound* ſalts are compoſed of acids united with alkalies; and may be divided into *double*, *triple*, and *quadruple*‡. The *double* ſalts may be ſubdivided into *neutral*, in which the acid is perfectly ſaturated with the alkaline part; *hyperoxea*, or *ſuperacidated*, in which the acid part predominates; and *hypoxea* or *ſubacidated*, in which the alkaline part abounds.

Each of theſe orders are further divided into *ſaline*, *earthy*, and *metallic* ſalts according to the different kind of baſe contained in each.

Of the 28 acids of the firſt order (ſee the annexed ſcheme) and the three alkalies of the ſecond order of Claſs I. together with the five primitive earths and the 17 metals, are formed the compound ſalts of which Claſs II. conſiſts.

The *irregular* ſalts conſiſting of the *triple* and quadruple ſalts, and of ſuch as are *imperfect*, either from an exceſs of acid or alkali, it ſeems hardly worth while, (as excepting a few, they do not very frequently occur) to reduce to a ſyſtem. For the ſake of regularity, however, we have allowed the latter, (viz. the imperfect) a place in the following ſcheme; and, impelled by the ſame motives, have given

* This laſt characteriſtic may ſerve to diſtinguiſh alkalies from the two alkalino ſaline earths, lime and barytes, and ſeems to be the property, though not excluſively, of all ſimple ſalts: as all pure and concentrated acids exhibit the ſame property.

† This name, which we have here ventured to introduce, as being ſhort and ſimple, and in every reſpect preferable to the barbarous denomination (potaſſinum) is derived from the Greek word σποδος, ſignifying *aſhes*.

‡ In the following ſcheme, this firſt diviſion is omitted, as tending only to create confuſion: and the triple and quadruple ſalts are ranged under the ſubdiviſions of the double.

given names to the genera of each order ſomewhat different from thoſe of order the firſt: although, when mention is made of any particular ſalt or ſpecies of ſalt, it will certainly be moſt convenient in common uſe to drop the additional ſyllables, by which the genera of theſe orders are here diſtinguiſhed, and retaining the ordinary generic term, diſcriminate them by changing either the termination only, or the termination and place likewiſe, of the ſpecific additament; e. g.

Such ſalts as are imperfect from an exceſs of acid, are beſt denominated by converting the adjective expreſſive of the baſe into a participle, a practice, which on other occaſions, though countenanced with the authority of a late eminent writer, ſeems awkward and ſtiff.

*Sales baſi defectivi, vel acido abundantes.*

| | | |
|---|---|---|
| Tartarus ſpodatus, ſive *cremor tartari* - - | | Tartaroxii ſpodici. |
| Vitriolum ſpodatum, vulgo *tartarus vitriolatus acidus* | | Vitrioloxii ſpodici. |
| ——— aluminatum, ſive alumen - | loco | ——— alumitici. |

Thoſe which are imperfect from an exceſs of alkali or baſe, may be aptly denominated by mentioning the baſe before the acid, and expreſſing the former ſubſtantively, the latter adjectively, as follows:

*Sales baſi excedentes.*

| | | |
|---|---|---|
| Spodium aerocraticum, aliter *ſal tartari*, *alkali vegetabile aeratum* | loco | Oxyſpodi aerocratici. |
| Ammonium aerocraticum, ſive *alkali volatile aeratum*, | loco | Oxyammonii aerocratici. |
| Calx aerocratica, ſive *creta* | loco | Oxycalcitidis aerocratici. |
| Natrum boracicum, ſive *borax* | loco | Oxynatri boracici. |

Should any arrangement be thought neceſſary for the *triple* and *quadruple* ſalts, they may be placed reſpectively under that *regular* ſalt which contains the acid moſt prevalent in their compoſition, and of which they may be conſidered as varieties; e. g.

Sales

*Sales Triplices.*

Tartarus ammoniaco—ſpodicus, ſive *tartarus ſolubilis volatilis.*
——— ſpodico—martialis, ſive ——— *martialis.*
——— ſpodico—natroſus, ſive *ſal polychreſtum Seignetti.*
Vitriolum muriœcico—ammoniacum, vel *ſal epſomenſis alkali volatili adunatus.*
Nitrum calcareo—murioecicum ſive *calx nitrata magneſiæ adunata.*
Hydragyrum muriaticum dulce *, ſive *mercurius ſublimatus dulcis.*

With reſpect to the ſub-diviſion made in the genera, ſuch as that of *muria* to *muria* and *epimuria*; it muſt be obſerved that the *epimuria natroſa* or aerated marine ſalt, differs from the *muria natroſa* or common ſalt, only as one variety differs from another. Accordingly, in theſe inſtances, neither the generic nor the ſpecific names are materially changed, a ſmall addition only being prefixed to the former.

* Some of the triple and all the quadruple ſalts are beſt expreſſed by their trivial names.

GENERA

## Genera Salium Neutralium.

| | | |
|---|---|---|
| 1. Vitriola | originem trahentia ab | Acido Vitriolico; *Sulphurocratia.* |
| 2. Nitra | | Nitroso; *ab eodem, aere partim privato* *Aponitra.* |
| 3. Muriae | | Muriatico; *ab eodem aerato* - - - - *Epimuriæ.* |
| 4. Boraces | | Boracico ceu Sedativo |
| 5. Fluoricratia {κρατος robur} | | Fluorico vel Fluoris. |
| 6. Arsenicratia | | Arsenicali. |
| 7. Barylithicratia | | Barylithiaco. |
| 8. Molybdænocratia | | Molybdænico. |
| 9. Photocratia | | Phosphorico. |
| 10. Electrocratia | | Electrino ceu Succineo. |
| 11. Oxycratia | | Acetoso: (*ab eodem aerato*) Epoxycratia. |
| 12. Tartari | | Tartarico; *ab eodem, vi ignis mutato,* Pyrotartari |
| 13. Oxalidicratia | | Sacchari vel Oxalidis. |
| 14. Cecidocratia | | Cecidico sive Gallarum. |
| 15. Citrocratia | | Citrorum. |
| 16. Melecratia | | Pomorum. |
| 17. Benzicratia | | Benzoico. |
| 18. Xylocratia | | Lignico. |
| 19. Gummicratia | | Gummoso. |
| 20. Camphoricratia | | Camphorico. |
| 21. Aerocratia | | Aereo. |
| 22. Galacticratia | | Lactis. |
| 23. Galamelicratia | | Sacchari lactis. |
| 24. Myrmecicratia | | Myrmecico sive Formicarum. |
| 25. Cyanocratia | | Cyanotico sive Cærulei Berolinensis. |
| 26. Steatocratia | | Steatino vel Sebaceo. |
| 27. Bombycicratia | | Bombycino. |
| 28. Zoolithocratia | | Calculi urinæ. |

## *Genera of Salts.*

1. Vitriols. 2. Nitres (*Aponitres*). 3. Murias (*Epimurias*). 4. Boraxes. 5. Fluoricrates. 6. Arsenicrates. 7. Barylithicrates. 8. Molybdænocrates. 9. Photocrates. 10. Electrocrates. 11. Oxycrates (*Epoxycrates.*) 12. Tartars (*Pyro-tartars*) 13. Oxalidicrates. 14. Cecidocrates. 15. Citrocrates. 16. Melecrates. 17. Benzicrates. 18. Xylocrates. 19. Gummicrates. 20. Camphoricrates. 21. Aerocrates. 22. Galacticrates. 23. Gala-melicrates. 24. Myrmecicrates. 25. Cyanocrates. 26. Steatocrates. 27. Bombycicrates. 28. Zoolithocrates.

## Specierum Salium Neutralium Specimen.

1. *Sales Salsi.* 2. *Sales Terreni.* 3. *Sales Metallici.*

Gen. I. Vitriolum — Vitriol.

| Latin | English |
|---|---|
| **Salsi.** (* Spec.) | **Saline.** |
| 1. Spodicum. | Spodic |
| 2. Natrosum. | Natrous |
| 3. Ammoniacum. | Ammoniacal |
| **Terreni.** | **Terreous.** |
| 4. Calcareum. | Calcareous |
| 5. Baryticum. | Barytic |
| 6. Murioecicum. | Murioecic |
| 7. Alumiticum. | Aluminous |
| 8. Siliceum. | Siliceous |
| **Metallici.** | **Metallic.** (Vitriol.) |
| 9. Platini. | of Platina. |
| 10. Auri, vel Solare*. | -- Gold, or Solar (Vitriol**.) |
| 11. Argenti, vel Lunare. | -- Silver, or Lunar (Vitriol**.) |
| 12. Hydrargyri, vel Mercuriale. | -- Quickfilver, or Mercurial (Vitriol**.) |
| 13. Stanni, vel Joviale. | -- Tin, or Jovial (Vitriol**.) |
| 14. Cupri, vel Venereum. | -- Copper, or Venereal (Vitriol**.) |
| 15. Plumbi, vel Saturninum. | -- Lead, or Saturnine (Vitriol**.) |
| 16. Ferri, vel Martiale. | -- Iron, or Martial (Vitriol**.) |
| 17. Zinci. | -- Zinc. |
| 18. Magnesii. | -- Manganese. |
| 19. Niccoli. | -- Nickel. |
| 20. Bismuthi. | -- Bismuth. |
| 21. Antimonii. | -- Antimony. |
| 22. Cobalti. | -- Cobalt. |
| 23. Arsenici. | -- Arsenic. |
| 24. Molybdæni. | -- Molydænum. |
| 25. Barylithii. | -- Barylithium. |

* Inepte *aurum, argenteum,* &c.

** Not *Golden, Silver,* &c. Vitriol.

# CLASSES ET GENERA SALIUM.

## CLASS I. *SALIA SIMPLICIA.* * * * * * * II. *SALIA COMPOSITA.*

### ORDO I. ACIDA.

GEN. I. { Vitrioloxys, vel Acidum Vitriolicum.
{ Sulphoroxys, vel ——— Sulphureum.
II. { Nitroxys, vel ——— Nitrofum.
{ Aponitroxys, vel ———Phlogifto-nitrofum.
III. { Murioxys, vel ——— Muriaticum.
{ Epimurioxys, vel ——— Aerato-muriaticum.
VI. Boracoxys, vel ——— Boracicum.
V. Fluoroxys, vel ——— Fluoricum.
VI. Arfenicoxys, vel ——— Arfenicale.
VII. Barylithioxys, vel ——— Barylithiacum.
VIII. Molybdænoxys, vel ——— Molybdænicum.
IX. Phofphoroxys, vel ——— Phofphoricum.
X. Electroxys, vel ——— Electrinum.
XI. { Acetoxys †, vel ——— Acetofum.
{ Epoxys, vel ——— Aerato-acetofum.
XII. { Tartaroxys, vel ——— Tartaricum.
{ Pyro-tartaroxys, vel ——— Pyro-tartaricum.
XIII. Oxalidoxys, vel ——— Oxalinum.
XIV. Cecidoxys, vel ——— Cecidicum.
XV. Citroxys, vel ——— Citrorum.
XVI. Meloxys, vel ——— Melicum, Malaceum, five Pomorum.
XVII. Benzioxys, vel ——— Benzoicum.
XVIII. Xyloxys, vel ——— Ligni.
XIX. Gummoxys, vel ——— Gummofo.
XX. Camphoroxys, vel ——— Camphoræ.
XXI. Aeroxys, vel ——— Aereum.
XXII. Galactoxys, vel ——— Galacticnm.
XXIII. Galamelioxys, vel ——— Sacchari Lactis.
XXIV. Myrmecoxys, vel ——— Formicarum.
XXV. Cyanoxys, vel ——— Cærulei Berolinenfis.
XXVI. Steatoxys, vel ——— Sebaceum.
XXVII. Bombycoxys, vel ——— Bombycinum.
XXVIII. Zoolithoxys, vel ——— Calculi Urinæ.

### II. ALKALIA.

GEN. I. Spodium.
II. Natrum.
III. Ammonium.

### ORDO I. NEUTRALIA.

GEN. I. { Vitriolum.
{ Sulphurocratium.
II. { Nitrum.
{ Aponitrum.
III. { Muria.
{ Epimuria.
IV. Borax.
V. Fluoricratium.
VI. Arfenicratium.
VII. Barylithicratium.
VIII. Molybdænocratium.
IX. Photocratium.
X. Electrocratium.
XI. { Oxycratium.
{ Epoxycratium.
XII. { Tartarus.
{ Pyro-tartarus.
XIII. Oxalidicratium.
XIV. Cecidocratium.
XV. Citrocratium.
XVI. Melocratium.
XVII. Benzicratium.
XVIII. Xylocratium.
XIX. Gummicratium.
XX. Camphoricratium.
XXI. Aerocratium.
XXII. Galactocratium.
XXIII. Galameliticratium.
XXIV. Myrmecicratium.
XXV. Cyanocratium.
XXVI. Steatocratium.
XXVII. Bombycratium.
XXVIII. Zoolithicratium.

### II. HYPEROXEA.

GEN. I. { Vitrioloxium.
{ Sulphuroxium.
II. { Nitroxium.
{ Aponitroxium.
III. { Murioxium.
{ Epimurioxium.
IV. Boracoxium.
V. Fluoroxium.
VI. Arfenicoxium.
VII. Barylithioxium.
VIII. Molybdænoxium.
IX. Phofphoroxium.
X. Elextroxium.
XI. { Acetoxium ‡.
{ Epoxium.
XII. { Tartaroxium.
{ Pyro-tartaroxium.
XIII. Oxalidoxium.
XIV. Cecidoxium.
XV. Citroxium.
XVI. Meloxium.
XVII. Benzioxium.
XVIII. Xyloxium.
XIX. Gummoxium.
XX. Camphoroxium.
XXI. Aeroxium.
XXII. Galactoxium.
XXIII. Galamelitoxium.
XXIV. Myrmecoxium.
XXV. Cyanoxium.
XXVI. Steatoxium.
XXVII. Bombycoxium.
XXVIII. Zoolithoxium.

### III. HYPOXEA.

*Salfa.*

GEN. I. Oxyfpodium.
II. Oxynatrum.
III. Oxyammonium.

*Terena.*

IV. Oxycalcites.
V. Oxybarytes.
VI. Oxymurioecites.
VII. Oxyalumites.
VIII. Oxyfilicites.

*Metallica.*

IX. Oxyplatinum.
X. Oxyaurum.
XI. Oxyargentum.
XII. Oxyhydragyrum.
XIII. Oxyftannum.
XIV. Oxycuprum.
XV. Oxyplumbum.
XVI. Oxyferrum.
XVII. Oxyzincum.
XVIII. Oxymagnefium.
XIX. Oxyniccolum.
XX. Oxybifmuthum.
XXI. Oxyantimonium.
XXII. Oxycobaltum.
XXIII. Oxyarfenicum.
XXIV. Oxymolybdænum.
XXV. Oxybarylithium.

† Vel fimplici vocabulo *Oxys.*

‡ Vel *Oxium.*

## SECT. VII. Metals.

*Metals* are inſoluble in water, ſhine with a peculiar ſplendor, and are the heavieſt and moſt opake of all bodies.

N. B. The ſpecific gravity of the lighteſt, when compared with water, is as ſix, of the heavieſt as twenty-four to one.

Metals, in general, appear to be acidifiable, like combuſtibles: and in fact, ſome of them, as zinc and arſenic, are not a little inflammable. When deprived of part of their phlogiſton, and united with a certain quantity of air (in which caſe they are ſaid to be calcined) they greatly reſemble earths: but differ from them in poſſeſſing a greater degree of ſpecific gravity; together with the property of tinging glaſs.

The metals at preſent known are 17 in number; and may be thus arranged.

| | |
|---|---|
| Noble Metals. | 1. Platina.<br>2. Gold.<br>3. Silver. |
| Intermediate Metal. | 4. Quickſilver. |
| Baſe Metals. | *Malleable.*<br>5. Tin.<br>6. Copper.<br>7. Lead.<br>8. Iron.<br>*Not Malleable.*<br>9. Zinc.<br>10. Manganeſe.<br>11. Nickel.<br>12. Biſmuth.<br>13. Antimony.<br>14. Cobalt.<br>*Acidifiable*.*<br>15. Arſenic.<br>16. Barylithium.<br>17. Molybdænum. |

* Tin and antimony have been very lately, in like manner, acidified by Meſſrs *Haſſenfratz* of *Paris*, and *Hermbſtadt* of *Berlin*, (*vid. Crell's Annalen.*)



SECT.

## SECT. VIII. COMBUSTIBLES.

*Combuſtibles* (excepting only the different ſpecies of inflammable gas and volatile alkali, which contain hydrophloge or the baſe of water, moſt of the metals, and perhaps the electric fluid), combuſtibles are, univerſally ſpeaking, the baſes of acids united with phlogiſton. Therefore, it ſeems moſt natural to ſay, not the baſe of ſulphur, but the baſe of the vitriolic acid; not the baſe of nitrous gas, but that of the nitrous acid; not the baſe of phoſphorus, but that of the phoſphoric acid. So that, in fact, if the ſtate in which a body is moſt uſually found, may be called its natural ſtate, acidity ſeems to be the natural ſtate of theſe ſubſtances, as it muſt be owned that water is of hydrophlogium. Indeed, the baſe of the muriatic acid has never been found either ſingle or in a combuſtible ſtate, combined with phlogiſton: and even the different æthers form acids on expoſure to air. In fact, all bodies ſeem to be more or leſs combuſtible, becauſe all bodies contain more or leſs phlogiſton; and it is on the expulſion of this principle, or on the converſion of it into ſenſible heat and light, that the combuſtibility of bodies depends. Many ſubſtances that are not combuſtible by atmoſpheric air, may yet be burned by the aſſiſtance of pure air, or by nitre, which contains this latter in great quantity in a concentrated ſtate. It is therefore better to confine the idea of combuſtibility to ſuch bodies, as being expoſed merely to the common air of the atmoſphere, give out light and heat on the application of a red heat, or of a heat equal to that of a common culinary fire. This definition neceſſarily excludes the diamond, which requires for its accenſion a much greater heat than the abovementioned. The leſs heat any ſubſtance requires in order to its combuſtion, the more combuſtible it is to be eſteemed.

1. The electric fluid therefore, which is accended in the greateſt degree of cold known in theſe climates, muſt doubtleſs be conſidered as the moſt combuſtible ſubſtance in Nature. 2. Next to this comes the pyrophorus of *Homberg*, which is kindled by a degree of heat ſomewhat below the freezing point. The third place in the order of accenſion is occupied by the phoſphorus of urine, or rather *Kunckel's* phoſphorus, which is decompoſed by a heat a little above this point: with this too perhaps the meteor called *Ignis fatuus* may be ranked. In the 4th rank may be placed fulminating gold, which kindles with the heat excited by gentle friction, together with various imperfect pyrophori, particularly the ſubſtance known by the name of black Wad. 5. Pulvis Fulminans. 6. Sulphur, which is inflamed

inflamed by a degree of heat greatly below ignition, together with the fulminating precipitates of M. *Bayen*. 7. Hay, which is undergoing the acetous fermentation. 8. Such ſubſtances as require actual flame, or (what is equivalent to it) the electric ſpark, in order to their combuſtion. Theſe are æther, the inflammable gaſes, vinous ſpirits and oily ſubſtances in general. 9. Such bodies as cannot be ſet on fire by the ordinary flame of a candle, or the momentary application of the electric ſpark, the heat afforded by theſe being too ſmall; and, to which, therefore, either a ſolid ignited ſubſtance, or a flame more powerful than ordinary, ſuch as that of Argand's lamp, or of the blow-pipe, muſt be applied. Theſe are gunpowder and other mixtures containing charcoal and nitre. 10. Zinc may be conſidered as one the of leaſt combuſtible ſubſtances in Nature; the other metals, and even iron, being not decompoſable by the common air of the atmoſphere without being expoſed to, what is called, a white heat, or elſe being reduced to extremely ſmall maſſes, ſuch as iron-filings, for inſtance, which burn in their momentary paſſage through the flame of a candle. If we extend the idea of combuſtion beyond theſe limits; the order of combuſtibility will be nearly as follows. Iron, copper, and other baſe metals, the noble metals, and laſtly the diamond, and ſome other ſtones and earths,

In order to underſtand the proceſs of combuſtion, it muſt be obſerved, that all combuſtible bodies (the noble metals are excepted by the definition given above) have a greater attraction for air than for phlogiſton, and that they attract phlogiſton merely in conſequence of the agency of a double affinity, at the very inſtant that the air is expelled from them. But this attraction for air takes place in different degrees of heat, according to the different degrees of attractive power with which the ſubſtances are reſpectively endued. If the combuſtible ſubſtance have a ſtrong attraction to air, and conſequently a weak one to phlogiſton, a very low degree of heat only is neceſſary towards its combuſtion: and vice verſa. Of each of theſe oppoſite caſes we have a notable inſtance in gold and phoſphorus.

Gold, and the noble metals indeed, being reduced merely by ſingle elective attraction, and the reduction of them being effected much eaſier than their calcination, appear to attract phlogiſton more powerfully than they do air. In mercury, on the other hand, the attractive powers of air and phlogiſtion ſeem to be more equally balanced, yet ſtill with a preponderance on the ſide of phlogiſton; for though a moderate degree of heat only is neceſſary for its calcination*, a par-

* It does not appear that the noble metals have been as yet abſolutely calcined or burned: but this is evidently owing to their comparative volatility.

tial

partial reduction, provided that light be but present, is effected with a still smaller portion of this fluid. The air indeed cannot be perfectly expelled from the calx of this metal without a much stronger heat than is sufficient to calcine it; but since this strong heat is accompanied with light which penetrates into the containing vessel, this latter principle is evidently attracted by the calx, which thus is reduced notwithstanding the tendency of the heat to separate the phlogiston from it.

Indeed, all the metals appear to attract phlogiston in preference to air: but the base metals do this to a certain point only. The attraction of the black calx of manganese to phlogiston is greater than it is to air: the calx however still retains a certain portion of the latter of these principles. Iron, as *Bergmann* observes, by exposure to heat (or rather actual fire) acquires phlogiston enough to become magnetic, but not sufficient for its reduction. Some other of the base metals are in a similar situation. But the reducing portion of phlogiston is always given to the calces of the base metals by means of a double elective attraction, which is a proof that the calces retain the last portion of their air with a greater force than that with which they attract the phlogiston necessary for their complete reduction. Mercury therefore seems to form the intermediate link in the metallic chain, between the noble or perfect, and the base or imperfect metals.

But all other combustible substances exhibit a stronger attraction for air than for the inflammable principle: since they stand not in need, as metals do, of a double decomposition, in order to enable them to receive air, and part with their phlogiston, or, in other words, to be burned: while, on the other hand, to enable them to receive the inflammable principle back again, and part with their newly acquired air, they must meet with a substance which is capable of decomposing them by a double elective attraction. Thus, phosphorus immediately on its exposure to air, unites with it by a single elective attraction, and forms phosphoric acid; which, on a metal being presented to it, is decomposed by a double elective attraction, the air of the acid together with part of the acid itself, uniting with the calx of the metal; and the base of the remainder of the acid forming phosphorus again with the phlogiston yielded by the metal during its calcination. The same may be said of sulphur, &c.

Charcoal is burned, as are all vegetable substances, by the vegetable principle uniting with the pure air of the atmosphere, or, (in close vessels) by its union with the pure air existing in nitre or in metallic calces. But this cannot be done without a certain degree of heat, diminishing the attraction of this base to the inflam-

 mable

mable principle of charcoal. Neither is the attraction of the vegetable principle, or of the base of combustible substances in general, for air and phlogiston, by any means reciprocal: as these bases never receive the latter and let go the former but in consequence of a double elective attraction taking place. This too is the case with the base or imperfect metals: for though manganese and iron, on certain occasions, part with their air and attract phlogiston in its stead; yet this is only to a certain point, viz. that at which they become soluble in acids. Beyond this point they retain their air obstinately, till some other substance takes it from them by a double decomposition.

The metals, on the contrary, are easiest deprived of their inflammable principle by the agency of a double elective attraction. This operation, by whatever means it is performed, is usually called calcination. Some, however, considering the analogy of names more than that of facts, have endeavoured to confine the term to the burning of metals and of lime. But lime is not burned, neither does it absorb air after calcination as metals do. It is best then to extend this term to every operation in which metals are divested of their inflammable principle, and united with air; whether this be effected by means of fire, water, or acids. Others, again, make a distinction between combustion and calcination. But in the case of metals, the only difference between combustion and calcination appears to be that, when a metal is burned, its phlogiston is dissipated in the form of light and heat; but when it is calcined by a double elective attraction, the inflammable principle is carried off in union either with the base of water, which we have called hydrophloge, or else with the base of the acid employed in the calcination: in every instance the principal effect is the same, the air remaining behind in union with the metal.—By the concentrated vitriolic acid metals are calcined, by attracting the air contained in a part of the acid, while their phlogiston is carried off by this deaerated part of the acid, forming with it sulphureous gas.—By the nitrous acid they are calcined by their inflammable principle uniting with the base of the acid, and forming nitrous gas; the aerial part being left behind united to the base of the metal.—The ordinary marine acid is not decomposed in this operation: but here the watery part by means of its base carries off the phlogiston of the metal with which it forms inflammable gas, leaving its air behind to assist in dissolving the metallic base.

All combustibles then (inflammable gas and perhaps the electric fluid excepted) are either totally or in part convertible into an acid by combustion. Thus sulphur generates the vitriolic acid, phosphorus the phosphoric acid, and all vegetable

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as well as animal, i. e. all organic ſubſtances generate the aerial acid. As an inſtance of the laſt of theſe proceſſes, we will take the flame of a tallow candle.— The vegetable principle of the tallow being by the heat applied in ſome meaſure diſengaged from the phlogiſton united with it, is ſeized upon by the circumambient air, with which it then forms the external blue flame of combuſtion: the internal or bright part being ignited only, and therefore not entirely decompoſed. This blue part of the flame it is which, when it ceaſes to burn, conſtitutes the aerial acid: and it is from this part of the flame alſo, that the heat is found chiefly to proceed. The ſlow combuſtions, unattended with light, which are ſaid to take place, when air paſſes from one of the bodies in which it was fixed and inelaſtic into another, are merely hypothetical, and have no exiſtence: although there is doubtleſs an actual but imperceptible exchange of the phlogiſton of one of the ſubſtances for the pure air of the other; as when phoſphorus taking air from the arſenical acid, reduces the latter by giving it the inflammable principle; alſo when charcoal receiving air from the phoſphoric acid, in like manner converts it into phoſphorus. And, in other caſes, where this ſlow combuſtion is generally ſuppoſed to take place without any tranſition at all, there is always a generation of an elaſtic fluid, compoſed of the principles ſeparated from theſe bodies by their coalition: as for inſtance, when charcoal decompoſes, and is at the ſame time decompoſed by water; the inflammable gas, which is here generated, conſiſts of the baſe of the water emitted together with the phlogiſton, which it has received from the coal in exchange for the air it had ceded to this latter ſubſtance. In like manner, nitrous gas is generated from nitrous acid and charcoal, or, from this ſame acid and metals. The ſame obſervation holds good with reſpect to the formation of hepatic gas, volatile alkali, &c.

Combuſtibles, therefore, may be defined, *bodies which are leſs ponderous and burn on the application of a leſs degree of heat, than metals; and, on being burned, are either totally or in part converted into an acid.*

N. B. Pure combuſtible matter is entirely acidifiable by combuſtion. It is likewiſe inſoluble in water; and mineral combuſtibles are accordingly thus defined by *Bergmann*, Act. Upſal. T. IV. But the livers of ſulphur, vinous ſpirit, and the different kinds of ſugar, are ſoluble in water: the two former evidently ſo from their containing a ſaline principle: which though not manifeſt in the laſt, may likewiſe be preſumed to exiſt in them from the conſiderable quantity of aerial acid yielded by them in fermentation, without any communication with the external air.

Com-

Combuſtibles may be arranged, as follows:

1. *Bitumens*, as Aſphaltes, Petroleum, Naphtha, Jet, Amber, (1. *European*. 2. *Indian*, or Copal.) Pit-coal, Turf.

2. *Vegetable Oils*. [A] pure, or almoſt pure.

| [a] *Unguinous Oils.* | [b] *Eſſential Oils.* | [B] *Mixed with other Matter.* |
|---|---|---|
| Butter, common.<br>—— of Cacao.<br>Chocolate.<br>Oil of Mace.<br>Tallow from the Rhizophora Mangel L.<br>Wax, of Bees.<br>—— from the Myrica cerifera. | Reſins.<br>Pitch.<br>Tar.<br>Balſams.<br>Æthers.<br>Camphor. | Wood and dry Vegetable in general. |

3. *Animal Subſtances*, as Lard, Suet, Marrow, Train-oil, Spermaceti, Bile, red part of the Blood, Dippel's Animal Oil. [*Excrementitious*] Cerumen Aurium, Stercus, Ambergriſe, Caſtor, Muſk.

4. *Soaps*, Acid, Alkaline, and Metallic.

5. *Sulphurs*. [Subſtances by combuſtion entirely convertible into an acid without leaving coal or other reſiduum.]

Sp. 1. Vitriolic Sulphur or *Brimſtone*.

Its Compounds are

1. Hepatic Gas.
2. The various Livers of Sulphur.
3. Sulphurated Metals, as *Orpiment*, *Cinnabar*, *Molybdæna*, (*mixed with other matters*) as *Pyrites*, *Galena*.

Sp. 2. Nitrous ſulphur or *Nitrous gas*. (An imperfect Sulphur, as being not, properly ſpeaking, combuſtible.)

Sp. 3. Phoſphoric Sulphur or *Phoſphorus*.

(Compound) *Phoſphoric Gas*.

Sp. 4. Vegetable Sulphur or *Charcoal*. (combined with Iron) *Plumbago*, with Hydrophloge, *Carbonaceous inflammable gas*. { A ſpurious Sulphur, which when burned, is converted into the aerial acid, leaving a very ſmall reſiduum of fixed Alkali.



6. *Oxaline*

Sp. 6. *Oxaline Sulphurs*, (Spurious as leaving a coal) or *Sugars*.
Sp. 1. Sugar (proper.)
Sp. 2. Honey.
Sp. 3. Manna.

7. Vinous Spirit.
8. Inflammable Gas.
9. *Pyrophori* (or bodies that burn in their proper fubftance, and are kindled at a very low temperature on expofure to the air.) 1. *Solid*. Pyrophorous of *Homberg*, Black wad, Hay undergoing the acetous fermentation. (Hemp, Wool, &c. in certain circumftances) and other imperfect Pyrophori. 2. *Aerial*. Ignis fatuus and other meteors, not accountable for on the principles of Electricity.
10. The Electric Fluid.

Pure combuftible matter is lighter than falts. The reafon is evident. Combuftibles in their converfion into falts abforb great quantities of air, which they retain in a condenfed ftate.

## SECT. IX. Mephitic Gases.

Under this head are arranged two fubftances, viz. *Nitrous Gas* and *Mephitis*, of which the former is compofed of the latter, and which therefore differ, not only in point of fimplicity, but in many other refpects. They agree, however, in feveral particulars, which render them unfit to be claffed under any of the heads of the preceding Sections: being totally different from heat and light, metals and water; being, though fluid and elaftic, not refpirable like air, nor capable of maintaining combuftion; wanting the folidity of earths, and the folubility of falts, and being fo far from poffeffing the inflammability of combuftibles, that they even extinguifh fire.

Mephitis by its great fimplicity feems to deferve a place among the elements: but nitrous gas is a compound of this, a fmall quantity of pure air and phlogifton. For a farther account of thefe two elaftic fluids, we beg leave to refer the Reader back to the third Section of this Chapter.

SECT.

## SECT. X. Magnetic Fluid.

The attraction of this very ſubtile fluid is evidently elective: and as no ſubſtance in Nature has yet been diſcovered that is free from the action of Chemical powers, it would be doubly abſurd to ſuppoſe the magnetic fluid to poſſeſs this privilege. We have, therefore, not ſcrupled to give it a place here among the ſubjects of Chemiſtry: although we are not able to determine under which of the preceding heads it ſhould be ranked, or, indeed, whether it ſhould be ranked under any of them.

## CHAP. III. CHEMICAL UNION.

### SECT. I. SATURATION.

WHEN a body is united to another, ſo as to form with it a ſeemingly homogeneous *tranſparent* ſubſtance, all the other primary properties of which are compounded of thoſe poſſeſſed by the component bodies in their ſeparate ſtate, this ſpecies of union is called *Chemical mixture.*

And when in the ſame circumſtances they form an opake body, the union is termed *Diffuſion.*

N. B. Diffuſion ſeems to depend on the intervention of a third body, which is united to the ſolvend, but will not combine with the menſtruum. *Examples.* Emulſions, the diffuſion of unguinous oils in water, by means of the volatile alkali, &c.

But when two bodies unite together, ſo as to form a ſeemingly homogeneous ſubſtance, poſſeſſing properties different from and not compounded of thoſe poſſeſſed by theſe bodies, when ſeparate, and deprived of the primary properties by which they were before generically diſtinguiſhed, this kind of union is called *Combination.*

When a body, which united with a certain quantity of another body is not able to unite with any more of it, that body is ſaid to be *ſaturated* with the other.

And if one of theſe bodies is capable of uniting with the other in any given quantity, it is a caſe of *ſimple* ſaturation.

But if neither the former can unite with the latter, nor the latter with the former, otherwiſe than in definite quantities, it is then a caſe of *double* or *reciprocal* ſaturation.

N. B. Simple and double ſaturation appear to be analogous, with regard to their reſpective cauſes, to mixture and combination; and both theſe pheno-

mena

mena ſeem to depend in a great meaſure on ſingle and double elective attraction. It is neceſſary to obſerve here, that we diſtinguiſh two kinds of ſaturation, as mentioned by authors, viz. the ſaturation of *combination* and that of *ſolution*. The former is indicated by the taſte and the action of re-agents; the other, by the ſpontaneous ſeparation of the ſuperabundant matter. The former is better termed *Neutralization*. In fact, the neutralized ſubſtance cannot be ſaid in this caſe to be ſaturated; as it will for the moſt part unite with more of the ſubſtance already combined with it. In vitriolated tartar, for inſtance, the vegetable alkali is ſaid to be ſaturated with vitriolic acid; but this alkali will alſo unite with an *exceſs* of acid, in which caſe, it is uſually ſaid to be ſuperſaturated; though with greater propriety it might be termed *ſuperacidated:* accordingly, in the claſſification of ſalts, we have included the ſalts of this order under the denomination of *Hyperoxea*, and thoſe, on the contrary, in which the alkaline principle predominates, under that of *Hypoxea*. In this ſpurious ſpecies of ſaturation, in ſhort, the properties of the acid part of the ſalt are deſtroyed by thoſe of the baſe, and vice verſa: but except in a very few inſtances, where the point of ſaturation and neutralization are the ſame, no real ſaturation takes place. It is therefore, not without much prejudice to the Science itſelf, that theſe two terms have been confounded by moſt Chemical writers.

*Genuine* ſaturation, or the ſaturation of *ſolution*, appears to conſiſt in the equilibrium of the force tending to unite the particles of the ſolvend to thoſe of the menſtruum, with the force by which the particles of the ſolvend attract each other*, added to that which, in conſequence of their difference in point of volatility, tends to ſeparate theſe two ſubſtances from each other.

Of the firſt kind of ſaturation, an inſtance may be obſerved in the ſpontaneous ſeparation of many neutral ſalts from their ſaturated ſolutions, by cryſtallization. Of the ſecond, we have examples in the impregnation of water with alkaline, ſulphuroxyc, nitrous, murioxyc, aeroxyc, or fluoroxyc gas; the water taking up a much greater quantity of theſe gaſes under an extraordinary degree of preſſure, than it does under the ordinary preſſure of the atmoſphere †.

* Viz. The force of coheſion ſubſiſting between the integrant parts.

† So inconſiderable indeed, is the force of attraction between water and many of theſe elaſtic fluids, that, on very high mountains, where the preſſure of the atmoſphere is greatly diminiſhed, the power of volatility is ſufficient almoſt entirely to overcome the force of attraction ſubſiſting between the menſtruum and the ſolvend; after a ſhort time, very little of the acid or alkali remaining in the water. Vid. *Sauſſure Voyage dans les Alpes.*

## SECT. II. Chemical Analysis and Synthesis.

The *integrant* parts of a body are thoſe which are homogeneous, both with reſpect to each other, and to the whole body.

The *conſtituent* parts of a body are thoſe which are heterogeneous, both with reſpect to each other, and to the whole body; and, which after ſeparation, being re-united in the ſame proportion as they bore to each other before it, form a body exactly of the ſame kind as that from which they were ſeparated *.

Chemical *compoſition* is the union of two or more heterogeneous bodies, or of the heterogeneous parts of two or more heterogeneous bodies into one ſeemingly homogeneous body.

Chemical *decompoſition* is the diviſion of a body into divers heterogeneous parts.

Chemical *Analyſis* is the diviſion of a body into its conſtituent parts.

Chemical *Syntheſis* is the union of ſome or all of the conſtituent parts of two or more heterogeneous bodies into one ſeemingly homogeneous ſubſtance.

When a body is ſeparated from another body to which it is heterogeneous, and of which, before its ſeparation, it formed a conſtituent part, it is called an *Educt*.

But if, before its ſeparation, it did not form a conſtituent part of the body; or if it conſiſts of different conſtituent parts ſeparated from divers heterogeneous bodies, it is called a *Product*.

* The conſtituent parts of bodies are divided by authors into proximate and remote: of both theſe, an inſtance occurs, in the ſubſtance commonly called Antimony, but which might, with greater propriety, be denominated *Sulphurated Antimony*. In this the metal itſelf and the ſulphur conſtitute the *proximate*, and the metallic earth and phlogiſton on the one hand, and phlogiſton and the ſulphureous baſe on the other, form the *remote* conſtituent parts.

CHAP.

## CHAP. IV. Chemical Instruments.

### SECT. I. Active Instruments.

THE *means* by which Chemiſtry effects the tranſpoſition of the heterogeneous component particles of bodies are, 1. the action of heat; and 2. the mutual attraction of the heterogeneous particles of bodies, on this account called chemical attraction, *vide page* 2*.

The *inſtruments* of Chemiſtry are the materials by which this tranſpoſition is effected. Theſe are divided by authors into active and paſſive.

The *active* inſtruments are ſuch ſubſtances as are of themſelves, and in conſequence of their very nature, capable of effecting this tranſpoſition. Theſe are, 1. *Heat*; 2. *Light*; 3. *Air*; 4. *Solvents*; 5. *Precipitants*; 6. *Re-agents*.

The *paſſive* inſtruments are ſuch ſubſtances as chiefly in conſequence of their form, are capable of aſſiſting in effecting this tranſpoſition.

Of the active inſtruments, the five firſt enumerated, are treated of under other denominations, in this work. The three firſt, under that of *ſubjects*, to which head, indeed, the whole of this diviſion naturally belongs. So that, conſidered in one light, they are the *ſubjects*, in another the *inſtruments* of the art. The *re-agents*, which form the laſt claſs of inſtruments, not being mentioned elſewhere in this work, we ſhall ſpeak of them here, after which we ſhall revert to heat, in order to conſider it more fully, than has hitherto been done, in the light of an active inſtrument of the art.

* The Chemiſt conſiders not repulſion: for if attraction be wanting, the particles of bodies will not unite. In this caſe they are ſeparate; which is ſufficient for his purpoſe; and the conſideration of any mutual repulſion that may take place between them, becomes unneceſſary.

## SECT. II. Reagents.

*Reagents* are ſubſtances that change their colour, on being mixed with certain bodies. Of theſe, the principal are, 1. The major part of the *blue and violet coloured juices of vegetables*, which are changed to a red colour by acids, and to a green by alkalies*. N. B. Syrup of violets is generally reckoned the beſt teſt for alkalies, and infuſion of Litmus for acids†. 2. *Solutions of copper* in the vitriolic and other acids, which become blue on the affuſion of volatile alkali‡. 3. *Tincture of galls*, which ſtrikes a purple, or (if the quantity of metal be large) a black colour with ſolutions of iron§. This, however, being at the ſame time a ſlow precipitation, partly belongs to another claſs¶. 4. The watery infuſion of the petals of the *red roſe* is changed from a very pale to a deep red, by the addition of a ſmall quantity of vitriolic acid. 5. The watery tincture of *Brazil wood* is readily changed from red to blue by alkalies; by acids it is made yellow. 6. The watery *tincture of Turmeric* is rendered brown by alkalies, and of a paler yellow than it was before, by acids.

* For exceptions to this rule, ſee *Macquer's Chemical Dictionary*, *Bergmann's Opuſcula*, Vol. 1. p. 126, Engl. Tranſlation: and *Becker Experimenta circa mutationem colorum vegetabilium*, *Gotting*. 1779. Many other changes of colour in the juices of vegetables are mentioned in the works of the authors abovementioned, as alſo of *Sieffert*, *Poerner*, *Roſe* and other German writers.

† Mr. *Watt*, *Phil. Tranſ.* Vol. LX. recommends an infuſion of the freſh leaves of Brown Cole in warm water, or, as this will not keep long, of the dried leaves of this plant in water acidulated with vitriolic acid, and afterwards neutralized with chalk or lime.

‡ The quantity of copper contained in four grains of vitriolic acid, is ſufficient to give a viſible tinge to three quarts of water, if the metal be precipitated by a proper quantity of the alkali, and afterwards re-diſſolved by the addition of more alkali.

§ Three quarts of water containing three grains of martial vitriol (i. e. $\frac{7}{24}$ gr. of iron) grows diſtinctly purple in leſs than five minutes on the addition of a ſingle drop of this tincture. The ſpirituous tincture is preferable to that made with water, as it is not apt to grow mouldy, like the latter.

¶ Some of the moſt modern Chemical writers, and our author among the reſt, have injudiciouſly confounded the reagents with *teſts* for mineral waters; and have accordingly deſcribed ſeveral precipitants among the reagents. *Bergmann*, on the contrary, brings theſe latter under the head of precipitants. Now, although the tincture of galls indeed may with propriety be reckoned a precipitant, as well as the Pruſſian alkali, which latter we have for this reaſon omitted in the enumeration given above; yet ſurely, ſyrup of violets and the reſt of the ſubſtances mentioned it it, do not by any means come under this denomination.

SECT.

## SECT. III. Heat, or Fire, as an Instrument.

We now come to *Heat*, confidered as an *inftrument*. Though, for the fake of convenience, we have deferred the confideration of it among the laft, yet we have given it the firft place in the lift of active inftruments, as it well deferves, being, to appearance at leaft, by far the moft active of any. And as Chemifts have been accuftomed to fpeak of this element under the denomination of fire, even where light is not in the leaft concerned, we fhall fometimes in the courfe of the following obfervations ufe the word heat and fire indifferently.

* The effect of fire upon bodies bears an exact proportion to the quantity or mafs of the body, the fize of the veffel, and the ftrength of the fire employed. Confequently the fame quantity of fire does not always produce the fame effect, the mafs or quantity of the body being different. Hence, in order that the intended effect may be produced upon any particular body, it is neceffary to have a thorough knowledge of the degrees of intenfity in fire, as well as of the means of fupporting it; as alfo of increafing and diminifhing it, according to the various views of the operator.

The ancients ufed to divide the intenfity of fire into four different degrees, and to determine each of thefe according to certain effects to be produced by them. But it is quite as accurate, if not more fo, to eftablifh five of thefe degrees, and to meafure them by *Fahrenheit's* thermometer.

The *firft* of thefe degrees is called the *digeftory*, and fhould produce a heat juft equal to that of the human body, or perhaps a little higher. It begins at the 34th degree of the abovementioned thermometer, and reaches to the 94th. At this degree, the fermentation of vegetables, and putrefaction of animal bodies take place. It is employed for the preparation of elixirs, effences, tinctures, and lack varnifhes, for the folution of metals and the evaporation of lixivia.

The *fecond*, called the *diftillatory*, commencing at the 94th degree of the abovementioned thermometer, extends to the 212th, the point at which water boils. It is at this degree, that the major part of liquids, fuch as fpirit of wine, oil, and water, boil and evaporate. Hence it is ufed for the diftillation of fpirit of wine, of water, of ethereal oils, and of urinous fpirits, for the rectifica-

* From the beginning of this paragraph to Sect. 2. of Chap. V. we follow M. *Wiegleb*, whofe diftribution of the active inftruments however is fomewhat different from that which we have given above. According to him, they are, 1. Fire; 2. Air; 3. Water; 4. Artificial Solvents; 5. Earths.



tion

tion of vegetable acids, as well as of the marine and nitrous, and for the preparation of varniſh for the uſe of painters.

The *third* degree is the *ſublimatory*. It begins at the 212th degree of *Fahrenheit*, and reaches to the 600th. It is under the fuſion of lead and tin, for the charging of organized bodies, for the fuſion of fixed alkaline ſalts, for the rectification of the vitriolic acid, and for the different kinds of ſublimation. In this degree towards the end of the operation the veſſels are brought to a dull red heat.

The *fourth* degree of heat, is called from the uſe to which it is generally applied the *fuſory*. It begins at the 600th and terminates at the 1500th degree, or at that at which iron melts, a metal, next to copper, the moſt difficult to be fuſed of any. At this degree all the imperfect metals are gradually deſtroyed, ores fluxed, gold and ſilver cupelled, pottery and porcelain-ware, tiles, and bricks baked, lime-ſtone converted into lime, and glaſs fuſed. At the higheſt point of this degree, all bodies give out a white heat. This degree is generally conſidered as the higheſt that culinary fire is ſuſceptible of; but this is only the caſe in the moſt common experiments, ſince it cannot be denied, that it may be raiſed ſtill higher, in which caſe alſo greater effects muſt neceſſarily be produced. Hence M. *Poerner*, by an uncommonly intenſe and continued fire, without any addition whatever, fuſed lime, chalk, and gyps, and converted them into glaſs, which no Chemiſt could do before him. In this operation the chalk was changed to a yellow, the lime to a greeniſh yellow, and the gyps to a perfectly tranſparent green glaſs.

The heat which is produced by the means of concave mirrors and convex lenſes, is to be conſidered as the *fifth degree*. Theſe inſtruments act with an inconceivable rapidity upon all bodies, and, in ſuch a manner, as no other fire could do. By theſe means wood may be burned to a coal, even under water; and *Hoffman*, with the aſſiſtance of a concave mirror made by *Hoeſen*, fuſed the Hungarian aſbeſtos in three ſeconds to a glaſs of a greeniſh yellow colour, and talc in one ſecond to a black glaſs. By this heat, lime and vitreſcent ſtones, Bohemian granates, the bones of oxen and Heſſian crucibles began to melt*. Theſe uncommonly great effects

* A ſixth degree might be eſtabliſhed from the conſideration of the ſtill greater effects of fire, when the ſubject is included in the cavity of a piece of ignited charcoal, and urged by a current of pure air, thrown upon it by means of a blow-pipe. Upon this principle M. *Erhmann*, of

effects of the Sun's heat can proceed only from this cause, viz. that the elementary matter of fire, the quantity of which however ought at the same time to be considered, acts in a state of the greatest purity possible: while, on the other hand, in all such fire as is procured by means of the combustible matters of our earth, it is constantly prevented by the other matters, such as air, water, &c. which burst forth and make their escape along with it, from acting with that power, which it otherwise would.

It would be very advantageous for the purposes of our art, if the fire of the Sun could be conveniently employed; but the application of it is attended with insuperable difficulties. For, first, the Sun does not shine continually: secondly, it is too often obscured by clouds: thirdly, the constant motion of the earth does not permit the focus to be kept for one minute at a time on the same spot: and the gradual direction of the mirror according to the course of the Sun is attended with many difficulties. We consequently are under the necessity of making use of the fire afforded us by terrestrial bodies. This we can have at all times, and continue it as long as we have occasion for it.

The substances best adapted to the maintenance and support of fire, are wood, charcoal, pitcoal, tan, turf, oils and spirit of wine; and in many cases also inflammable air.

*Wood* can be used in those cases only, in which a blazing fire is wanted, and where the smoak, which cannot be avoided in a wood fire, will do no harm. Hence it may be used in small distillations with a naked fire, for the making of bricks and tiles, pottery, and porcelain, for burning lime, and gyps, and many other similar works. Of the many different kinds of wood, the beach and the hornbeam are undoubtedly to be preferred; next to these the oak; and, in general, all

of *Strasburgh*, Versuch einer Schmelz-kunst, *Strasburgh*, 1786, has invented a machine, by which not only talc, and Bohemian granate, but the most refractory substances, and even rock crystal, are completely fused, some of them in the space of a few seconds, and the last in less than a minute. In short, (the purer kinds of calcareous earth excepted, and such as contained no other acid besides the aerial, white transparent calcareous, and Icelandic spar, stalactites, English chalk, marbles with a small quantity of iron, and even marles with less than $\frac{1}{8}$ of clay in their composition) nothing withstood the force of this machine, which is worked by water; but seems to have no advantage over a pair of bellows. It is to be observed, that most of the fusions that have been effected upon very refractory substances, have been performed in crucibles of chalk, or upon glass, or some other substances, which acted as a flux upon the subject matter: but here it was in contact with nothing but ignited charcoal, which served as a crucible, but could not operate essentially as a flux. [E]

heavy and ſolid kinds of wood. Next to theſe are the alder, aſpen, birch, fir, aſh, and lime-tree; and, in general, all the lighter kinds of wood. The former excite a greater heat, burn longer, and leave, after the flame has ceaſed, a coal of which the parts ſtill cohere; on the other hand, the latter exhibit more flame, give out leſs heat, burn and conſume faſter, and leave but little coal behind. Therefore, where a briſk and lively fire is wanted, and the goodneſs of the coals is out of the queſtion, the latter are to be preferred. For the purpoſe of making a briſk and lively fire, they ſhould be cloven rather ſmall.

*Charcoal*, or wood-coal, when it has been duly burnt throughout its whole ſubſtance, produces but a glimmering fire: when in conſequence of a briſk draught of air, the air mixes with the matter of fire, which eſcapes from it, it alſo produces flame. In a determinate ſpace, a more active fire can be procured by it, than by means of wood. It is fitter for ſmall chemical operations, as it is more eaſily managed. Charcoal made of the more ſolid kinds of wood is the moſt preferable. When it has been once made thoroughly red hot and quenched, it throws out leſs heat afterwards, and only glimmers away very ſlowly till it is conſumed.

*Tan* made up into cakes, is alſo fit for firing, eſpecially where a gentle and continued fire is advantageous. It does not produce a great heat, nor exhibit any flame; and conſumes but ſlowly with a glimmering light, and a continual ſmoak.

*Pit-coal* and *turf*, may alſo be uſed with advantage, by way of ſaving wood and charcoal. In different countries, where wood is ſcarce, they are ſolely uſed in all operations, in which fire is requiſite. There is a great difference in turf with reſpect to its internal quality. The heavy bituminous kind, called *Peat*, is preferable to the light common *turf*. The good quality of coal depends in like manner upon the proportion of the bituminous to the earthy particles, and upon the abſence of the vitriolic acid. Both may be rendered fitter for uſe, by being charred and deprived of their ſulphur, by a proceſs ſimilar to that which is performed upon wood, which may be done in large furnaces, built for that purpoſe.

*Oils* and *ſpirit of wine* are uſed only in furnaces of a particular conſtruction, made of tin, when there is need of a gentle and long continued heat. For this uſe, the cheapeſt expreſſed oils will ſuffice, ſuch as coarſe fiſh-oil; the ordinary ſorts of petroleum, and the oils which may be obtained by a proper apparatus in charring pit coal. All ſuch oily bodies, on account of the great quantity of ſoot, which they inevitably produce, and which is very apt to fall down into the oil, ſo that they frequently ſet each other in a blaze, are not very fit for uſe, and hence the uſe of them has been diſcontinued. Neither can the collection of a great

uſe,

quantity of ſoot round the wick be avoided; this ſhould be continually taken off, leſt the lamp ſhould extinguiſh of itſelf. Although the uſe of ſpirit of wine is not attended with theſe inconveniences, yet the expence of it is not ſo great, that the amount of it generally exceeds the value of the article, obtained by it; on this account, we may very well diſpenſe with this ſort of fuel. With reſpect to the application of inflammable air to ſmall chemical operations, which may be expelled from divers vegetable bodies, as beans, &c. M. *Goettling* has given a deſcription of it in his *Almanack for Chemiſts, for the year* 1785, p. 185.

## SECT. IV. THE REST OF THE ACTIVE INSTRUMENTS.

The ſecond active inſtrument in Chemiſtry is *Air*. Under this appellation, is compriſed, not only the air, which ſurrounds bodies, but that alſo which is incloſed in them.

As no fire can ſubſiſt without air, and as the artiſt can do very little without fire; the application of air will be neceſſary in every operation in which fire is requiſite; as will be explained when we come to give a more particular deſcription of the various operations of the art. The principal efficacy of this inſtrument proceeds from an elaſticity peculiar to itſelf, which in an eſpecial manner acquires additional force from the action of fire; next to this, its activity depends in a great meaſure on its fluidity and ſolvent power.

By its elaſticity it promotes the operation of fluid menſtrua in cloſe veſſels, and in open veſſels the evaporation of bodies. In fact, it takes up the evaporating particles, and thereby ſhews great ſolvent powers. In this reſpect, it is indiſpenſably neceſſary in all inteſtine motions that are to be excited in bodies, as well as in the production of fire by means of the combuſtion of inflammable bodies.

The third active chemical inſtrument is *Water**. This is not only the true and genuine menſtruum of all ſalts, gums, mucilaginous and gelatinous ſubſtances, but it is alſo very efficacious in various other chemical operations; as in the diſtillation of ethereal oils, the ſublimation of ſedative ſalt, the cryſtallization of ſalts in general, and in the purification of ſpirit of wine from the extraneous ſubſtances, that are united with it and render it impure.

* This ſubſtance acts no otherwiſe than as a ſolvent, and is therefore included in our fourth diviſion. But as it is the moſt univerſal menſtruum in Nature, it may not be improper to give it a more particular conſideration [E]

With

With respect to the solution of salts in water, these peculiar properties offer themselves to our consideration: viz. that it cannot dissolve an equal quantity of every salt, and that each particular salt requires a certain quantity of water for its solution. Farther, that this solvent power may be promoted by an additional degree of heat, and, on the contrary, diminished by heat or an additional degree of cold; and that, at the same time that it is perfectly saturated with one particular salt, it is capable notwithstanding of dissolving a portion of another*.

Water is also efficacious in the composition of bodies with respect to combining their particles with each other; as may be plainly perceived in the making of mortar, and in the setting of gyps, or plaister of Paris. But where it already forms a constituent part of bodies, it may become the efficient cause of the fluidity of the separated parts; of which we have an instance in the mineral acids.

The fourth kind of active chemical instruments are *artificial Menstrua* or *Solvents*†. By this appellation are understood different fluids, which are produced or compounded by art, and which acting powerfully upon other bodies, decompose and divide them into their smallest particles, and at the same time receive these particles into their interstices. With such powers are endowed the fluor acid, the various solutions of alkaline and neutral salts, those of the dry solid acids, inflammable spirits, and expressed and ethereal oils. But these will be treated of more properly elsewhere.

Finally, the *Earths* may also in a manner be reckoned among the active instruments, being adapted to vitrification, purification, and to separations and combinations of every kind; and must be therefore necessarily considered as co-operative on these occasions.

* *Elleri* Tractatus Physico Chemici, p. 254, & 364.

† Some of these menstrua however may in the strictest sense be stiled natural; the acid of lemons, for instance, that of ants and some others. [E]

## SECT. V. PASSIVE INSTRUMENTS.

The *Paſſive Inſtruments* now remain to be deſcribed. Under this denomination come ſuch inſtruments as exhibit no active powers, but are merely paſſive, and ſerve only for the purpoſe of applying the active means abovementioned, and to facilitate their operation. To theſe may be referred inſtruments of all kinds, or the whole of the apparatus uſed by Chemiſts, for attaining their various intentions.

This apparatus may be diſtributed in a general way into four claſſes. To the firſt, belong the different kinds of *furnaces*; to the ſecond, the *veſſels*; to the third, the *inſtruments*, properly ſo called; and to the fourth, the *lutes*. We ſhall now take a ſeparate view of each of theſe Claſſes.

By *furnaces* are underſtood certain veſſels, conſtructed for the purpoſe of receiving fire, retaining it within proper bounds, and applying it to certain veſſels, containing a matter to be changed by it. For this purpoſe, a ſuitable conſtruction is requiſite, which muſt be regulated by the following conditions:

The conditions, upon which a determinate quantity of fuel is capable of acting with greater power upon the bodies, to which the fire is applied, are theſe, viz:

1. The furnace ſhould be ſufficiently ſtrong, that it may retain the heat long enough.

2. The interior cavity of the furnace muſt to be of a ſufficient and proportionate width*.

3. The grate of the furnace ſhould not be placed too near the aſh-hole, neither ſhould the diſtance between the iron bars be too great or too ſmall. The utmoſt diſtance ſhould be half an inch.

4. Directly over the furnace, there ſhould be erected a chimney or tower, contracted towards the top.

5. The force of the fire is much increaſed, by leaving the regiſters which are contrived in the corners of the upper part of the furnace, open, as well as the doors of the fire-place and aſh-hole.

* The elliptical form of the interior part of the furnace, which in former times was deemed neceſſary, is by no means ſo uſeful as it was once ſuppoſed.

6. As

6. As alſo by conducting the air from without, by a long tube to the aſh-hole.

7. By putting the air into motion by means of bellows: and farther,

8. By uſing ſeveral pair of bellows together of a ſufficient magnitude.

9. By directing the bellows from different parts of the fire-place to the center.

10. By loading theſe bellows with heavy weights, that they may put the air into a quick motion.

The excellence of furnaces depends no leſs on their ſtructure, than on the materials of which they are built. The marks by which the goodneſs of them is aſcertained, are, that they make the fire of a ſufficient ſtrength, and do not ſuffer it to be ſcattered abroad and waſted; that they keep it up to an equable pitch and with little expence, and, finally, determine it to the ſpot, upon which it is deſigned to act with the greateſt force.

For the purpoſes of our art, many different kinds of furnaces have been contrived. There are ſome, which are adapted to ſeveral different, and others, which are only fit for certain particular operations. Some are ſquare, ſome round, and others elliptical; ſome are portable, other fixed; ſome again are ſimple, and others complicated. They derive their names either from their ſtructure and form, in conſequence of which the bodies to be treated, are expoſed in a certain manner to the fire; or from the way in which the fire is introduced into their cavity; or from the inventor, or from the effects produced. In general they differ much in point of ſize.

Furnaces are uſually built of bricks, which are joined together in two different ways, either by laying them on their ſides, or their edges, Thoſe furnaces, however, that are conſtructed with bricks laid edgewiſe, muſt neceſſarily have leſs thickneſs than the others. Now, the thinner the ſides of the furnace are, the ſooner the heat will pervade them, and conſequently eſcape the ſooner, and therefore act with leſs power upon the bodies, which are expoſed in them to the fire. On the contrary, the thicker the furnace is, the longer it will retain the heat, and act with the greater power upon the bodies, upon which a change is to be effected. Hence, thoſe furnaces, in the ſtructure of which the bricks are laid flat, have been found beſt adapted to the retention of heat and to the excitation of the fierceſt fires.

There are alſo furnaces made of tin-plates; theſe would not, however, be fit for retaining the heat, and would likewiſe ſoon be burnt and deſtroyed by the fire, if they were not defended on the inſide with a thick coating of clay. Furnaces of a kind ſimilar to theſe may alſo be caſt in iron.

Upon the whole, it is a general rule in the conſtruction of furnaces, that the fire will be encreaſed in proportion as the air has acceſs to it. Now as the air can paſs more freely to the fire, when the grate is ſo conſtructed as to be ſomewhat diſtant from the aſh-hole, and at the ſame time of a tolerable ſize; in ſuch a furnace, it is evident that the ſame quantity of fire muſt act with greater efficacy upon the bodies to which it is applied. But it is not only owing to the capacity of the aſh-hole, but alſo to a proportionably large grate, that a greater quantity of air forces itſelf into the fire, contained in the furnace; it is likewiſe owing to the greater quantity of rarified air, which is encloſed in the aſh-hole. For, this rarified air occaſions the denſer external air alſo to force its way to the fire by its power of expanſion. The more capacious therefore the aſh-hole is, and the more rarified air it contains, the greater will be the quantity of the external denſer air, and the ſtronger its tendency towards the fire.

The faſter moreover the rarified air eſcapes from the furnace by the ſuperior regiſters, the faſter will freſh air, which is not yet rarified, enter into it. But the faſter it enters, with the greater force it ruſhes towards the fire, and proportionably increaſes the effects of this latter. The ſame means, therefore, by which the air is rapidly and abundantly introduced into the furnace, increaſes, at the ſame time, the activity of the fire. Hence this effect may be expected alſo from a tower ſet upon the furnace, becauſe the motion of the air and its proportionate impulſe towards the fire are particularly augmented, by the rarified air being made to paſs from a wide place to a narrower one, and afterwards to eſcape through this latter.

In order that the air may increaſe the activity of the fire, it ſhould not only have a free acceſs, but a free egreſs alſo. This latter object is attained by opening the door of the fire-place, and likewiſe by keeping open the regiſters in each of the upper corners of the furnace. Hence to the conditions which are requiſite for the producing a violent action in the fire, this too may be added, that as well the regiſters in the upper part of the furnace, as the doors of the aſh-hole, ſhould be left open.

The motion in the fire is conſtantly regulated by that of the air; but the motion of the air is particularly accelerated, when the air is made to paſs from a wide ſpace to a narrower. The reaſon is this, the air being compelled to paſs through a narrow ſpace, and being preſſed and ſqueezed together in its paſſage, will, immediately on its egreſs, be the more expanded again, and by this means diſplace the air, which it finds at the aperture of the narrow paſſage. Hence the egreſs of the air out of the furnace will be continually accelerated; and conſequently the

accefs of frefh air to the fire be promoted, and the fire become more and more powerful. In the fame manner the velocity of the current of air will be increafed, when the air is conducted to the fire-place from a diftance, through a long tube, or forced into it by means of bellows. Hence too it follows of courfe, that the greater the number of bellows that are employed at a time, the more the fire muft be increafed, efpecially when they are directed from different quarters to one point, and are loaded with weights befides.

By the abovementioned means united, fo powerful a fire may be raifed, as might feem incredible. But it is not even requifite to employ all thefe means together; as it is fufficient to fix a fand-pot with a tube to the top of the furnace, and to bring the air from a diftance into the afh-hole through a long tube; by which means the fire may be certainly increafed to a very great degree, as is plainly demonftrated by M. *Pott's* furnace, in which no other than thefe three expedients are employed.

Sufficient demonftration has now been given, of what confequence it is in the conftruction of chemical furnaces, to make a proper draught for the air, and that the augmentation of the fire depends entirely upon the air. The quantity of motion in this latter, determines the intenfity of action of the fire. Hence it is eafy to underftand the different methods by which, according to the various views of the artift, the power of fire may be diminifhed or weakened upon the bodies, which are expofed to it. This effect is produced in two different ways; either by preventing both the accefs and egrefs of the air, or by fmothering the fire, and, as it were, choaking it up. The former depends on preventing the motion of the air, and is effected by fhutting up the lower doors and the fuperior regifters of the furnace, or by ceafing to blow with the bellows; or by removing the tower from the top of the furnace, or the tube from underneath it. The fecond method is, to cover the fire more or lefs with afhes.

From the circumftances abovementioned, it evidently appears, how neceffary it is for a Chemift to underftand the conftruction of furnaces, that he may be able himfelf to point out how they ought to be difpofed, and know which kind of furnace is the moft convenient for his purpofe, as alfo to be able to improve fuch as are defective, and occafionally to conftruct new ones.

All furnaces, in whatever way they are conftructed, confift of two, or at moft of three pieces. The firft, or the lower piece, compofes the afh-hole, and reaches to the grate. The fecond, or the middle piece, begins at the grate, and comprifes the whole of the cavity in which the fire is lodged. The third, or upper piece,

piece, makes the place in which, ſtrictly ſpeaking, the operations are performed, and which is ſituated between the fire-place and the upper aperture of the furnace, into which are put the veſſels containing the materials deſigned for the operation. To this upper piece alſo appertain the regiſters, which muſt be two or three fingers wide, according to the ſize of the furnace; and be ſituated, if the furnace be of a quadrangular form, in the four upper corners of it. In a furnace, which conſiſts only of two pieces, the upper and middle chamber are made into one.

Every furnace which is compoſed of three pieces, ought to have two large apertures, one for the fire-place, and the other for the aſh-hole; but if it be compoſed of two pieces only, it has nothing but the aſh-hole, becauſe the fuel is put into it at the top. The former ought to have regiſters, the latter none.

Each of the larger apertures of a furnace ſhould be made to ſhut with a door; each regiſter likewiſe muſt be furniſhed with a plug. Both of theſe blocks contribute greatly to the management of the fire, as may be inferred from what has been mentioned above.

Of the furnaces uſed by Chemiſts, the principal are, the diſtilling furnace, the ſand furnace, the reverberatory furnace, the wind furnace, and the eſſay furnace.

The *diſtilling* furnace is either of a ſquare or cylindrical form, and is immoveable. It ſerves for the diſtillation of waters, ethereal oils, inflammable ſpirits, and vinegar.

The *ſand* furnace, which takes its name from the ſand-pot, the veſſel chiefly uſed in it, is deſigned for various operations, ſuch as digeſtion, diſtillation*, evaporation, and ſublimation. This furnace may be either portable or fixed, according to its ſize. The form of it is generally quadrangular. If, inſtead of a ſand-pot, which veſſel we ſhall deſcribe a little farther on, a copper caldron is ſet in this furnace, it may alſo ſerve for a *Balneum Mariæ*.

The *reverberatory* furnace, reſembles that immediately preceding in its whole ſtructure, excepting that acroſs it, juſt over the fire-place, two ſtrong iron bars muſt be fixed in the brick work, for the purpoſe of ſupporting the retorts that are to be laid on it. It is uſed in the diſtillation of mineral acid ſpirits, empyreumatic oils, volatile ſalts, phoſphorus, and many other ſubſtances. Theſe veſſels, which are either of ſtone-ware or glaſs, are expoſed to a naked fire, on which account they

* Profeſſor *Weigel's* deſcription of a new retort-furnace is worthy of the Reader's attention. It is to be found in his Chemico-mineralogical Obſervations, *Chemiſche-mineralogiſche Beobachtungen. Breſlaw*, 1779. Vol. II. p. 113.

ſhould be coated with a compoſition of clay, &c. in order to prevent them from eaſily burſting. For the purpoſe of increaſing the fire, a tower may alſo be added to this furnace. This furnace may likewiſe be conſtructed in ſuch a manner, that many retorts may be ſet upon it at a time, and wrought with the ſame fire. The ſmaller and more ſimple of this kind of furnace, may be made ſo as to be portable.

The *wind* furnace, which is called alſo the *melting* furnace, is uſed for fuſion, detonation, calcination, evaporation, and even ſublimation, when this latter operation is performed with a ſmall quantity of materials. It is conſtructed either of caſt or of hammered iron, or elſe of brick work. The former of theſe are of a cylindrical form and portable, the latter fixed and ſquare. They are generally wrought by bellows, when the operation of fuſion is performed in them. They both belong to that kind, which conſiſts only of two pieces. It is very convenient to have in that which is made of plate-iron, over the opening of the aſh-hole, another round hole cut out, and a tube ſeveral yards long accurately fitted to it, through which the air may be conducted to it from a diſtance. In this caſe, however, the door of the aſh-hole, which otherwiſe is open, ought to be conſtantly kept ſhut*.

The *aſſaying* furnace is uſed only in metallurgic operations, namely, in the fuſion of metallic ores in ſmall, in the cuppellation of the metallic bodies, which have been obtained from them; it may alſo be employed for calcining metal in ſmall quantities. It is a portable furnace, made of hammered iron, and ſtrongly coated with clay on the inſide. It may however be compoſed likewiſe of bricks.

Hitherto all that is neceſſary to be ſaid about the furnaces, which are almoſt daily uſed in the practice of Chemiſtry, has been mentioned. We ſhall now therefore proceed to the deſcription of the compound furnaces. The principal of theſe is, the *Athanor*, or *Sluggard's* furnace, the ſtructure of which is as follows: many furnaces of different kinds, ſuch as reverberatory, ſubliming, calcining, diſtilling, and digeſting furnaces are built in a row, in ſuch a manner, that their ſeveral fire-places have a communication with each other. On one ſide, or even in the middle of theſe, there is a high tower capable of containing a conſiderable quantity of coals, and from which the fire may be diſtributed into all the different furnaces at one and the ſame time. Theſe furnaces ſhould, however, be ſo ſituated, that thoſe

* An accurate deſcription of a furnace of this kind, in which the fierceſt fire may be excited, is found in *Beaumé's* Chemie. Experim. & raiſonnée, Tome I. p. 7, & 20. Alſo in *Weigel's* Chem. Min. Obſervations, Tome II. p. 147.

which

which have need of an intenſe heat, may be nearer to the tower, than thoſe which require a more gentle degree of heat. So that in this furnace various, and thoſe very different, operations, ſuch as the diſtillation of oil of vitriol, or other mineral acids, as alſo the diſtillation of different waters, and of ſpirit of wine and its rectification: likewiſe the different proceſſes of cementation, calcination, evaporation, and digeſtion, according to the various views of the operator, may be carried on at the ſame time, and with the ſame fire, night and day without interruption*.

This furnace, it is true, appears to be very uſeful to the artiſt, and particularly recommends itſelf to him in point of convenience. But it is alſo attended with ſo many difficulties and inconveniences, that the uſe of it has not met with general approbation. For, firſt, the fire cannot be conſtantly kept in that order, which the nature of theſe manifold operations may require, which however ſhould here be the chief object. Secondly, operations are ſo far from being ended in a ſhorter time in this furnace, that they proceed ſlower, and cannot be finiſhed to ſo much perfection for the want of the requiſite degree of heat. Thirdly, it is very ſeldom that a Chemiſt has occaſion to perform ſuch different operations to which theſe furnaces are adapted, at the ſame time; beſides it is to be conſidered that a furnace of this kind is ſoon burnt through, and the repair of it amounts to a conſiderable ſum, frequently more than equal to the value of the fuel ſaved by it; ſo that, in fact, it neither ſaves time nor money.

The other part of the chemical apparatus conſiſts of the different kinds of *veſſels*, properly ſo called. Theſe are made either of glaſs, earthen-ware, or metal.

* For the ſake of convenience, different Chemiſts have invented *univerſal compound* furnaces, in which various operations may be performed. Of this kind is Dr. *Black's* furnace, a deſcription of which may be ſeen at the end of this volume. Of the ſame kind too is *Becher's*, which is deſcribed in his *Laboratorium portatile*, as alſo the *galley* furnace, that will hold ſeveral retorts together. [A]

The late Dr. *James Price's* portable furnace deſerves likewiſe to be mentioned in this place. A deſcription of it may be ſeen in the new Edition of *Lewis's* Diſpenſary, printed for *Nourſe*, in the *Strand*. Neither muſt we omit to mention here, the capital improvement on portable furnaces in general, by lining them with fire-bricks, ſuggeſted by Mr. *More*, Secretary to the Society for the encouragement of Arts, Manufactures, and Commerce, in an Eſſay on Portable Furnaces, publiſhed in the year 1786, in the Tranſactions of that Society: in this Eſſay, he has alſo propoſed a portable furnace of his own invention, which merits great commendation, as well for its ſimplicity as its cheapneſs. It is made of ſtrong plate-iron, and lined with fire-bricks. [E]

Glaſs

Glaſs veſſels the moſt commonly uſed, are *retorts*, *matraſſes*, *phials*, *heads of alembics*, *adopters*, *bowls*, *mortars*, *funnels*, *cylindrical glaſſes* and *bottles*.

A retort is a veſſel conſiſting of a hollow ſphere, terminating in a tube, ſomewhat contracted towards its mouth. It is uſed for various kinds of diſtillation and ſublimation. The ſhape of the ſpherical part, and the width of the tube, which is commonly called the *neck*, are not the ſame in all retorts. For ſome matters are apt to expand or foam, during their diſtillation, and others to come over in a ſolid form. In the former caſe, therefore, the belly of the retort ſhould not be round, but of a pear-like, or oval form, by which means the materials are prevented from boiling over. Theſe, by the Germans, are called *Engliſh retorts*, from their having been uſed firſt in this country. In the latter caſe, the retort ought to have a wide neck; and, the mouth in particular, muſt not be too ſmall, but have a conſiderable diameter, (at leaſt half an inch) in proportion to the ſize of the retort, otherwiſe the neck is liable to be ſtopt up by the riſe of the thick matter, and the veſſel conſequently to burſt.

The neck of a retort may come out of its belly in two different ways: it may either proceed from the middle of the belly, ſo that the tranſverſe ſection of this latter ſhall be nearly parallel to the axis of the neck; or the neck may come out directly from the upper part of the ſphere. The latter are moſt convenient; while the former are uſeleſs, becauſe the riſing vapors cannot ſo conveniently enter into the neck, and a conſiderable part of them flow back again into the retort, a circumſtance which does not happen in the others.

The neck of this retort is not bent unneceſſarily. It muſt have this ſhape, that the vapors, which have been propelled into its aperture, may be condenſed there in the form of drops, and upon that directly diſtill over freely into the receiver. It is alſo of conſequence that this free courſe of the vapors ſhould be promoted, eſpecially with reſpect to ſuch fluids, as on account of their natural viſcidity come over with great difficulty, and which, even independently of this circumſtance, are apt to occaſion a ſtoppage in their paſſage. On account of theſe two circumſtances, the retort ſhould always be ſet in the furnace in ſuch a manner, that its neck may incline conſiderably downwards.

There is alſo a kind of retort which in the top of the ſpherical part, behind the neck, or ſometimes on the ſide of its belly, has a hole, furniſhed with a ſhort thick tube of an equal diameter throughout, and is ſecured with a glaſs ſtopper. Theſe are called tubulated retorts, and are uſed only for thoſe kinds of diſtillation, in which it is requiſite for the materials to be added gradually. They are, however,

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certainly more apt to fly during the operation, becaufe they are fubject to many alterations of heat and cold, in confequence of the materials being poured into them, and alfo becaufe they are unequally expanded by the fire juft at the above-mentioned aperture, where the glafs is of an unequal thicknefs.

A *Matrafs* is a hollow fphere, from the upper part of which arifes a ftraight conical mouth, fomewhat tapering towards the top. The length of this neck is quite arbitrary; but it feldom exceeds twice the diameter of the fpherical part. The bottom is fometimes round, and fometimes flat. The fize of the fpherical part alfo is very different; and hence the matrafs obtains various names. Such as are not quite half a foot wide, are called *feparating matraffes*, and thofe, whofe diameter is from fix inches to one foot, are called *common matraffes*; but if the diameter approaches to two feet, they are called *mafter matraffes*. This is the greateft width of a matrafs; becaufe if it exceeds two feet, it is no longer called a matrafs, but a *receiver*, or a *balloon*. There is alfo a difference obferved in their ufe. Receivers ferve only to collect thofe fluids, which are expelled from matraffes and retorts, but matraffes are employed in diftillations, digeftions and fublimations. Though indeed the larger kinds of matraffes may alfo be ufed for receivers.

There is another circumftance ftill to be obferved refpecting the large receivers, which fhews the neceffity there is for them. This is, that fome fluids ufually come over in diftillation, not in palpable drops, but in the form of an elaftic vapor, which is able to burft the receiver, if it be not capacious enough for the vapor to expand itfelf in it. This danger, indeed, might be eafily avoided, if a vent was to be given to the confined air; but as in this cafe the air could not be let out, without part of the fpirits being loft at the fame time, by way of remedying this defect, very large capacious veffels are to be felected, which will retain the expanded vapors without any danger, till they are condenfed. Hence fometimes receivers are made that are more than two feet in diameter. It is by no means neceffary, however, to augment the length of the neck in the fame proportion, but rather the contrary, fince the necks of even the largeft receivers muft be fhort enough to admit the necks of the diftilling veffel into their bellies.

*Phials* differ from matraffes in no other refpect than in having longer and narrower necks of equal dimenfions throughout, the length of which may be from four to fix times the diameter of the fpherical part. They are employed in long continued digeftions; becaufe a long and narrow neck prevents the menftruum from being fo eafily diffipated by evaporation, and in fuch abundance as it is in matraffes.

traſſes. They are however not abſolutely neceſſary; the common matraſſes may very well ſerve all thoſe purpoſes, for which phials were formerly thought to be requiſite. When the body of a phial is of an oval form, it is called the *philoſophic egg*, a denomination, which it obtained in thoſe times, when Alchemiſts were continually brooding over their darling chimerical notion, the Philoſopher's ſtone.

*Heads*, or *Capitals*, are veſſels, which are ſet upon alembics, for the purpoſe of collecting the vapors as they ariſe, and ſometimes of throwing them into another veſſel. Thoſe which conduct the vapors, when collected, into another veſſel, have a beak, and are therefore called *beaked*, or *open* capitals: but thoſe, which retain the vapours within themſelves, have no beak, and are called *blind* capitals; theſe latter, however, are now diſuſed. They have ſometimes alſo a circular hole ground in the upper part, which may be cloſed by a glaſs ſtopper; but moſt of them have a knob at that place, round which a piece of thread is tied for the purpoſe of ſuſpending them by it. The tube which deſcends from the capital, muſt neither be too narrow, nor muſt the glaſs of which it is made, be too thin: for when it is too narrow, it is eaſily ſtopped up by the volatile ſubſtances which are depoſited in it, and burſts: but when it is too thin, it is eaſily broken by the preſſure of the receiver.

*Adopters* are tubes, which grow narrower at one end, and are from half a foot to two or three feet long. They are ſometimes of the ſame width throughout, but ſometimes they belly out in the middle, in which part they have, not unfrequently, an aperture, with a ſtopper to it, or elſe a ſmall tube. They are fixed between the diſtilling veſſel and the receiver, as well for the ſake of procuring more room for the expanded vapors, and thereby preventing the cracking of the veſſels, as alſo for that of obſerving the commencement, progreſs, and end of the diſtillation. When glaſs adopters are uſed, large ſtone receivers may be ſubſtituted for the glaſs ones. The necks of burſted alembics may be employed for the purpoſe.

Glaſs *bowls* ſerve both for the ſpontaneous deliqueſcences of ſaline bodies in the open air, and for gentle evaporations. They ſhould not however have any projecting rim, as this might cauſe them to fly on the application of heat. Inſtead of theſe, the bottoms of alembics may be cut off and uſed, and alſo china bowls may be employed with advantage.

*Glaſs mortars* ſerve chiefly for pulverizing ſharp corroſive ſalts, and for mixing them with other ſubſtances; or elſe for pulverizing other hard bodies, when there

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is reaſon to fear that by uſing metal mortars, they might be rendered impure by the admixture of metallic particles detached in conſequence of the friction*.

*Glaſs funnels* are uſed for the purpoſe of decanting acrid juices, and of ſeparating ethereal oils from the water, which comes over in diſtillation along with them. On account of this latter uſe they alſo bear the name of *ſeparating funnels*. When they conſiſt of an oblong roundiſh belly, which at top is contracted into a narrow neck, ſo that it may be ſecured with a ſtopper; and are beſides furniſhed with two arms, one on each ſide, but at bottom terminate in a narrow tube; they have by ſome been called *maidens*.

*Cylindrical Glaſſes*, are veſſels of a cylindrical form, and furniſhed with a projecting rim at top. They are uſed when any ſubſtance is to be ſeparated from a fluid with which it is mixed, and to be ſuffered to ſettle. They are alſo employed in the filtration of liquids.

*Glaſs bottles* are uſed of various kinds, and for many different purpoſes. We ſhall only make this general obſervation concerning them, that round bottles are preferable to ſquare ones, becauſe theſe latter are more apt to fly in extreme cold weather, and are more eaſily damaged by an external blow, than the round ones.

To the glaſs veſſels, which are neceſſary for chemical operations, may be referred alſo the whole of the *apparatus* requiſite for the preparation of the various kinds of *air*, of which a deſcription may be ſeen in the Works of Dr. *Prieſtley*, and others†. Neither muſt we omit to mention here that convenient and uſeful inſtrument, the areometer‡, by which the gravity and denſity of fluids is aſcertained. It is uſed for determining the proportion of ſpirit contained in brandy, intended for ſale; the ſtrength of beer, brine-ſprings, and mineral

* Mortars are now made by Mr. *Wedgewood*, which on account of their durability as well as their power of reſiſting the action of acids, entirely ſuperſede the uſe of glaſs. [E]

† Particularly *Cavallo*. See his Treatiſe on Air. Quarto. [E]

‡ A more accurate and particular account of this inſtrument is found in *De Machy's* Deſcription des Arts et Metiers, Lib. 1. Chap. 7. The uſe of it is very ancient, as may be ſeen from an Epiſtle of *Syneſius*, biſhop of *Ptolemais*, in which Epiſtle he deſcribes this inſtrument with great accuracy to the learned *Hypatia*: (vid. Epiſt. 7. in *Syneſius's* Works.) So that it was already known in the beginning of the fifth century, if not ſooner. This inſtrument muſt doubtleſs have fallen into oblivion; and *Father Kircher*, who ſaw it at a German artiſt's of the name of *Tolden*, by whom it was uſed for inveſtigating the degree of ſaltneſs of water, did no more with reſpect to this diſcovery than republiſh it.

acids: whence it muſt alſo be diſcriminated by the different names of ſpirit-beer, and brine-proof, becauſe this inſtrument muſt have a particular conſtruction for each of theſe purpoſes. It conſiſts of a hollow glaſs ſphere, terminating in a long tube, which is hermetically ſealed at top, and is marked on its ſides with various lines, one below another at equal diſtances. Before the tube is cloſed, a quantity of leaden ſhot, ſufficient to keep it upright in the water, is poured into it. It is alſo made of braſs plates, and gilded on the outſide.

Another general obſervation to be made with reſpect to glaſs veſſels is, that thoſe glaſſes, which are of a green or even a black colour, or which have been fuſed with the ſmalleſt quantity of pot-aſh, and by the fierceſt and longeſt continued fire, are the moſt durable. For the purpoſe of ſuſtaining a fierce fire, the thineſt glaſs ſhould always be choſen. Flint glaſs is for the moſt part unfit either for ſuſtaining an intenſe fire, or for holding of corroſive acid ſpirits.

The earthen veſſels that are chiefly neceſſary in Chemiſtry, are, Earthen retorts and Matraſſes, Crucibles, Dutes, Capſules, Cupels, Teſts, Muffles, Cementing pots and Aludels.

*Earthen retorts* are thoroughly baked veſſels of pottery-ware, that will ſtand the fire, and in figure are almoſt ſimilar to the abovementioned glaſs retorts. They have an oblong belly, the bottom of which however is not, like that of the glaſs retorts, rounded off in the form of a caldron or kettle, but broad and flat, ſo that they can ſtand on it; the neck is bent ſomewhat downwards, but not ſo much as in the glaſs retorts. They are employed in ſuch operations, as require an intenſe heat, and therefore they muſt be placed upon the naked fire.

*Stone-ware* or *earthen matraſſes*, differ from the retorts juſt deſcribed, merely by a neck riſing ſtraight upwards from their belly. The diſtillers of aqua fortis and oil of vitriol, uſe no other matraſſes for their diſtillations than theſe, which they lay rather obliquely in the furnace. And hence among theſe people, they bear the name of retorts alſo.

*Crucibles* are hollow truncated cones, cloſed at the truncated part, which forms the bottom, while the upper part, which is open, has ſometimes one, and ſometimes three angles projecting from it.

There are, properly ſpeaking, two kinds of crucibles, both of which differ greatly from each other, as well with regard to their external appearance, as alſo, to their other properties, which ſolely depend on the matter of which they are formed. One ſpecies of them is made of pure ſand and clay; the other of clay and

and molybdæna, or black lead. Both kinds derive their names from the countries where they are manufactured: the former, are called *Hessian*, the others, *Ipser* or *Passau* crucibles.

Besides the abovementioned composed of sand, or molybdæna mixed with clay, crucibles, according to *Pott*, may also be made of other materials, which are not inferior to the common ones. They may be made, in the first place, of crude and burnt clay, mixed together; these are chiefly adapted to the fusion of glass and of brass: but in other operations, which are carried on in wind furnaces, they cannot be used, because the air easily causes them to fly. Secondly, of crude and burnt clay, and a small quantity of litharge or minium. Thirdly, of crude and burnt clay, and a small portion of colcothar. Fourthly, of crude and burnt clay, and a little vitreous spar. Fifthly, of crude clay, sand and chalk. Sixthly, of burnt clay and chalk. Seventhly, of crude and burnt clay, or only of one of these two, steatites and some litharge. Eighthly, of Spanish chalk and burnt talc, which kind has been found fittest for the fusion of refractory artificial glasses. Ninthly, of clay, and a little Saxon serpentine stone.

As to the *Hessian* crucibles, those are the best which are sufficiently solid and strong, have no black spots on them, are of a brown red colour throughout, and emit a clear sound, when struck. They are manufactured in two places only in Hesse; viz. in Great and Little Almerode, and are, on account of their extraordinary solidity, exported not only all over Europe, but also to more remote countries. The Saxon crucibles are, however, not much inferior to them, among which may be included principally, those manufactured at Waldenburg, (the praises of which have been long ago celebrated by *Basil Valentine)*, as also those made at Skele, Burgel, and Magdeburg.

These crucibles are employed in the fusion, calcination, detonation, and vitrification of metals, salts, and other substances. But as they are somewhat porous, they are, in various ways, acted upon by several matters, which it is necessary to keep in fusion in them during several hours, such as salts, copper, lead, and regulus of antimony; whence they are sometimes apt to fly, at other times are corroded, and perforated. For the same reason too, they cannot hold the glass of lead in fusion for the space of an hour without being perforated by it.

This inconvenience, however, may in some measure be avoided, by inclosing the crucible, containing the matter to be fused, within another larger *Hessian* or *Ipser* crucible, and filling up the space between both with sand or pulverized glass,

glafs, or elfe it may be coated with a proper coating, which mode of prefervation we fhall defcribe, when we come to treat of lutes and coatings*.

In order that the Heffian crucibles may be ufed more than once, which may be done very well in operations of fhort duration, care fhould be taken to prevent their being broken by external accidents. The crucibles, therefore, fhould never be fet immediately upon the grate, but a piece of brick fhould be previoufly put underneath them, fo as to prevent the cold air, which rifes through the grate, from ftriking directly upon them; after this the operation muft be begun with a gentle and equable heat. When the operation is over, the crucibles fhould be taken out with heated tongs, and immediately after the fufed matter is poured off, be laid again among the coals, or inverted, and covered with fome other veffel, in order that they may cool fpontaneoufly, without coming into contact with the cold air.

The *Ipfer* crucibles are not only made in the place, the name of which they bear, and which is fituated in the neighbourhood of Ratifbon, but alfo in *Hafner-zell*, a town of Upper Auftria, and likewife in two other towns of Bohemia, *Boehmifch-brodt* and *Procop*. Thefe are neither fo folid and hard as the Heffian, nor fo brown and rough; but rather feel foft and greafy, are of a black colour, and blacken the hands. They are much more durable in the fire than the Heffian; though not fit for all the purpofes to which thofe may be applied. They cannot contain, even for the fhorteft fpace of time, any kind of falts in fufion, becaufe they are eafily corroded and perforated by them; confequently, no matter, which contains the leaft falt, can be fufed in them, and for this reafon, they are not fit for the fufion of glafs of lead, which is as injurious to them as that of falts. Many affert, that they are likewife perforated by antimony; but experience has proved that they are fit for the refining of gold, which is done by means of antimony; and for the fufion of antimony itfelf. Their greateft utility confifts in this, that metals of the moft difficult fufion, fuch as gold, filver, copper, brafs, and bell-metal, can be fufed in them. It ought to be obferved, however, that the ductility and colour of the noble metals, is a little altered by thefe crucibles, when they are ufed for the firft time; but when they have been in the fire feveral times, they grow foft and crooked, and, confequently, unfit for farther ufe.

* *I. A. Weber*, in his *Phyfico Chemical Magazine for Phyficians, Chemifts and Artifts*, Vol. I. Berlin, 1780, p. 101, affirms, that the Heffian crucibles, by rubbing them on the infide with linfeed oil, and afterwards ftrewing green glafs reduced to a fine powder upon them, may be prepared in fuch a manner, that they will hold the glafs of lead, in the moft intenfe fufion, for twenty hours together.

To

To the article of crucibles, alſo, are referred a particular kind of veſſels, which bellying out in the middle, are ſomewhat contracted at top and bottom, and are furniſhed with a lid. In the language of the art, they are termed *Dutes* *. They are commonly uſed in aſſaying, for ſeparating ſmall portions of the noble metals from their ores.

*Capſules* are ſmall ſaucers about two inches broad, either made of pure clay, or of clay mixed with ſand. They are employed for the purpoſe of roaſting ſamples of ores, and of ſmelting them with lead, when their value is to be aſcertained.

*Cupels* are ſmall ſaucers of a particular form. They are made of a paſte, formed of the bones of calves, ſheep, or fiſh, which have been calcined to whiteneſs, and reduced to a very fine powder, mixed with elixated aſhes and water. This paſte is moulded into a proper form with certain inſtruments, to be deſcribed hereafter; then ſprinkled over with dry bone-aſh, reduced to a fine powder, and dried gently. They are of different ſizes, and from two to three inches broad: but when they are larger, and about half a foot broad, they are called *Teſts*, and are made of mere elixated wood-aſhes, in like manner ſprinkled on the inſide with the aſhes of bones. Both kinds are emyloyed in the purifying of gold and ſilver with lead. For the lead, by means of the fire, diſſolves the whole of the inferior metal or metals, uſed in the fuſion mixed with the gold and ſilver, forming a droſs together with them, and conſequently ſeparates by degrees from the noble metals; after which it fuſes to glaſs, and enters into the ſubſtance of cupels, which, for this reaſon, ought to be of a porous matter. The whole operation is called *Aſſaying*, and is done in the aſſaying furnace above deſcribed.

*Muffles* are veſſels made of clay, of a ſemi-cylindrical or ſometimes of a hemiſpherical form, cloſed at the back part, and open before, with ſome ſemi-circular apertures on each ſide. They ſerve to cover the abovementioned teſts and cupels, ſo that no coals or aſhes may fall into theſe veſſels.

*Cementing pots* are cylindrical veſſels, the height of which is arbitrary, but which are at moſt ten fingers only in diameter, or of a ſufficient width for the hand to be introduced into them with eaſe. They are uſed for the corroſion of metals, the refining of gold, and giving it a higher colour, as alſo for the purpoſe of mixing and fuſing many metallic ſubſtances together. They are made of the

* As we have no name in our language for the veſſel here deſcribed, we have ventured to introduce this term from the German. [E]

ſame

ſame materials as the Heſſian crucibles. In default of a pot of this kind, a common crucible, cloſely covered with a lid made of a brick, may be ſubſtituted for it; or two Heſſian crucibles are made uſe of, or, if the matter which is to be operated upon will permit it, two Ipſer crucibles; one of which is inverted upon the other, and the place where they join carefully luted.

Laſtly, *Aludels* are ſpheres made of ſtone or earthen-ware, with a ſhort neck projecting at each end, by means of which one globe may be ſet upon the other. They have alſo ſometimes a beak on their ſide, like the capital of an alembic, but generally none. Six or more of them are put one upon the other, (the uppermoſt of which muſt not be open) and then they are luted. In former times, they were employed in the ſublimation of ſeveral ſubſtances, and a particular advantage was ſuppoſed to ariſe from it: this apparatus, however, proved conſtantly uſeleſs; whence they have been entirely neglected, and are now mentioned, merely as as an inſtance of the ſingular whims that ſometimes poſſeſſed the brains of our anceſtors.

The following utenſils of *metal* are neceſſary for the Chemiſts: Retorts, Matraſſes, Cucurbits, *Papin's* Digeſtor, Pots, Kettles, Sand-pots, Cones, Iron-rings, Tongs, Shovels, Spatulas, Iron Ladles, and Fire Hooks.

*Metal Retorts*, either ſimple or tubulated, are caſt only in iron. They are preferable to any others on account of their durability, and are uſed for the diſtillation of ſuch ſubſtances, as require a fierce fire, but are not ſo corroſive withal as to attack iron; for this reaſon theſe retorts are not fit for the diſtillation of acid ſpirits.

Metallic *matraſſes* may alſo be caſt in iron, and may be, when laid obliquely in a reverberatory furnace, uſed for the diſtillation of the ſubſtances juſt mentioned. Matraſſes of copper or pewter, furniſhed with capitals of the ſame kind of metal, may be very aptly employed in diſtillations in ſand, but by no means in the preparation of tinctures.

Metallic *cucurbits* are made of copper plates joined together, and tinned over on the inſide, that they may not be covered ſo ſoon with verdegriſe, an effect, which almoſt any fluid that is ſomewhat ſharp and acrid will produce upon copper. Theſe veſſels are ſet in the diſtilling furnace deſcribed above.

Upon theſe cucurbits metallic *capitals* are ſet, which may be made either of copper or pewter. Some of them are hollowed out at the top in a particular manner, or rather ſurrounded by a veſſel of the ſame metal, having the ſhape of a caldron, which is raiſed ſtill higher than the capital, and is to be filled with cold water, with which the capital muſt be entirely covered. This ſerves to condenſe and

cool the vapors which riſe into the capitals, and which, when by degrees this grows too hot, and can no longer perform the office of a refrigeratory, are let out in a condenſed ſtate through a cock, fixed in the pot for the purpoſe; and cold water is poured into the pot afreſh. Theſe capitals are called *Black-a-Moor's heads.*

*Papin's Digeſtor* is a cylindrical veſſel of metal, about one foot high, and ſix inches in diameter. It ought to be made either of caſt-iron or of braſs, one inch in thickneſs, and be turned very ſmooth on the inſide. At the ſurface of this cylinder, an aperture is made, which is a little ſmaller than the interior capacity of the cylinder, but muſt be of an oval form. A plate is then made of the ſame thickneſs as the cylinder, which plate is alſo oval, like the aperture, but half an inch broader. To this plate is fixed a ſcrew, which paſſes through a thick piece of leather, with which the plate is covered. This plate, covered with the leather, is now introduced into the cylinder through the oval aperture, and turned in ſuch a manner, that, when it is pulled, the hole is cloſely ſhut up from the inſide. The projecting ſcrew is then thruſt through a hole, made in the middle of a ſtrong broad bolt, and by means of the nut ſcrewed on to the plate very tight; and, in this manner, the veſſel is ſhut as cloſe as it is poſſible for it to be*.

The uſe of this machine is as follows: a quantity of ſolid bones are put into it, and covered with water, then the machine is ſhut up, and ſet upon a ſlow coal fire, in conſequence of which, the bones will be entirely diſſolved in a ſhort time, ſo that nothing will remain of them, but the mere earth which ſerves them for a baſis. In the ſame manner copal and amber may be perfectly diſſolved in expreſſed or ethereal oils.

The metallic *pots* uſed in Chemiſtry, are made of caſt-iron, and chiefly employed in the evaporation of ſaline lixivia. To the ſame purpoſe, iron *kettles* or *caldrons* are very well adapted: while, for others, copper and braſs ones are found neceſſary.

*Sand-pots* are cylindrical veſſels, which are commonly made of caſt-iron, but ſometimes of tin or copper plates. The former are preferable, as being more durable, and alſo maintaining the heat longer than the latter, though (in the beginning at leaſt) they require a little more fire to heat them. The bottom of this veſſel is

* Vid. *Ludolf's* Einleitung in die Chemie, Erfurth, 1752, p. 506, Tab. XV. Likewiſe *Rudiger's* Syſtematiſche Anleitung zur allgemeinen Chemie, Leipſic, 1756, § 466. Tab. III. Fig. 4. 5. [A] In the Stockholm Tranſactions, Vol. XXXIV. p. 3, Profeſſor *Wilke* has given an improvement of this machine, with figures, under the title of 'Forſok til en ny inrättning af Papini digeſtor, til oekonomiſka behof,' i. e. An attempt towards a new conſtruction of Papin's digeſtor, for Oeconomical purpoſes. [E]

convex,

convex, that it may present a more extensive surface to the action of the fire. It ought to have at top, projecting one inch and a half from it, a rim to support it, when it is put into the above-described cupelling furnace, which must be just wide enough to receive it. The rim also must have a notch cut out on one side of it, reaching to about its middle, that the bended necks of the retort may conveniently be laid in a proper direction. This vessel is filled with ashes, sand or iron filings, and into these is put the glass, containing the materials designed for the operation.

When the vessel, which we have just now described, is made of copper-plate, and has no notch on the side of it, and consequently resembles a deep cylindrical copper caldron, it is called a *Balneum mariæ* or Water-bath, and may be set in the abovementioned furnace instead of the cupel. Into this, the matrass which contains the materials is put, being previously loaded with a leaden ring, which is fastened to the belly of the matrass by means of strings, and adds a weight to the matrass sufficient to prevent its being tossed to and fro by the motion of the water in the pot. Upon this the pot is closed with a lid, which has a hole in the middle, through which passes the neck of the matrass. Besides this large aperture, there should be another smaller hole on one side of the lid, through which fresh water may be introduced to make up for the deficiency occasioned by the evaporation. This bath is employed in the distillation of the most volatile matters, which are capable of being distilled by the heat of boiling water.

*Cones* are vessels made of brass or copper, terminating in a point, and are six, or at the most, nine inches in depth, and four or six inches wide at the top. Into these are poured all substances in a state of fusion, that contain reguline matter, that the heavier metallic matter may separate from the lighter part or dross, and after it has settled and cooled, be conveniently turned out. The quantity of the matter, which sinks to the bottom, is commonly small, and, therefore, the vessel is contracted into a point at the bottom, that this matter may the easier be collected into one mass. Copper and brass are preferred for the composition of this vessel, because they are susceptible of a better polish than other metals are, whence the advantage arises, that the melted mass which has been poured into a polished cone of this kind, is easier thrown out again from it: neither indeed is it so subject to rust as others, or else iron would answer the same purpose. Pewter and lead are not at all proper; as, on the one hand, they could not resist the heat of the metallic bodies in a state of fusion, which are poured into them, and consequently would be apt to be melted likewise: and on the other, as the melted bodies,

on being poured into them, would eaſily be rendered impure by the admixture of theſe metals. For, it may even be of bad conſequence, when the copper or braſs, of which the cone is made, is mixed with a little lead or tin.

*Iron-rings* are uſed for breaking off the necks of matraſſes and retorts, for which purpoſe they are previouſly made red-hot.

*Tongs* are of two kinds. One kind is uſed for coals only: the other ſerves to lift the crucibles out of the fire.

*Shovels* are made of ſtrong iron-plates, and uſed for introducing coals into the furnace, as alſo for taking the aſhes out of it.

*Spatulas* and *iron ladles*, which ought to have long handles, ſerve to put the materials into the crucibles, and likewiſe the latter, to lade out the leys, with other ſimilar uſes.

A *hook* is an iron rod, with a crooked extremity, and about a foot and a half long; it ſerves to ſtir metals in fuſion in the crucibles, and other bodies.

The other utenſils, which are made of wood, paper, linen, ſtraw or other materials, ſuch as frames for ſtrainers, wooden peſtles, filtering baſkets, paper filters, bellows, ſtraw cuſhions, and filtering bags, it may be thought ſufficient to name without giving any further deſcription of them.

The place where the whole chemical apparatus is kept, and where at the ſame time the operations are carried on, is called the *Laboratory*. It ſhould be ſufficiently capacious and light; not liable to take fire, and furniſhed with a chimney. The apparatus may be diſpoſed in ſuch a manner, that the furnaces ſhall ſtand againſt the four walls of the room, and the remaining ſingle veſſels be kept in proper repoſitories. With regard to theſe matters, however, every one muſt be governed by the nature of the place and other accidental circumſtances.

Finally, the different *lutes* or *cements* ſtill remain to be deſcribed, which in many caſes are indiſpenſably neceſſary. Under theſe denominations are comprehended ſuch tough viſcid mixtures, as grow ſolid after they are dried, and with which, either the junctures of veſſels are ſecured, or the veſſels themſelves coated; or the cracks in glaſſes and other veſſels filled up.

Now theſe ſubſtances ſhould be of different kinds, according to the different uſes for which they are intended. The diſtilling veſſels cannot be joined ſo cloſely, that no kind of opening ſhall be left between them, through which the bodies, ſubjected to the operation, may evaporate. In order therefore to prevent this evaporation, ſome kind of luting muſt be had recourſe to. Again, the materials to be diſtilled, are in general very various; being ſometimes watery, ſometimes

of an oily, ſometimes of a ſpirituous, ſometimes of a volatile urinous, and at other times, of a corroſive acid nature. Hence it is evident, that the artiſt, according to the nature of the ingredients to be diſtilled, if he means to ſave them all, ſhould alſo have lutes, not only of one, but of different kinds. The ſelection muſt, in fact, be made, with a reference to the activity of the materials to be diſtilled; and the lute ſhould be of a nature, not to be acted upon at all, or at leaſt very little, by the ſubject matter.

When the matter to be diſtilled is merely watery, or even when together with water ſome oil comes over, the junctures of the veſſels need only be covered with a paſte, made with flour, with which a piece of paper ſeveral inches broad, and long enough to be wound ſeveral times round the junctures, is to be beſmeared, and preſſed cloſe into them. Boiled paſte will anſwer this purpoſe better than that made with cold water.

In the diſtillation of ardent and urinous ſpirits, a good paſte may likewiſe be employed; but it is better to cover the junctures with a wet hog's or calf's-bladder, and, for the ſake of greater ſecurity, to tie it with packthread. A luting of common loam, mixed up with a very thin ſolution of glue in water, is likewiſe not amiſs in the diſtillation of urinous ſpirits; as alſo of quicklime mixed with cheeſe-curds or the whites of eggs. The latter, however, as it is apt to dry very faſt, ought to be ſpread upon a piece of linen, directly after it has been mixed, and put round the junctures.

But in order to retain corroſive acid ſpirits, ſuch a lute muſt be uſed, as is neither corroded nor diſſolved by them. Common loam mixed with chopped flax, and tempered with ox-blood, is the cheapeſt; but this is better when mixed with equal parts of clay which has no calcareous earth in its compoſition: a better ſtill is clay alone. But the beſt of all is, when pure clay well waſhed is kneaded to a ſtiff dough, together with linſeed oil boiled down to a varniſh, and mixed with chopped hair and flax.

It muſt be obſerved beſides, with reſpect to the abovementioned materials, which are employed for the purpoſe of luting veſſels tight and cloſe, that they ought to be perfectly dry before the operation is begun. For, till they are dry, they cannot make any reſiſtance to the riſing vapors, which however make their appearance at the beginning of the operation; and, conſequently, the operator would, in ſuch a caſe, hardly attain his purpoſe.

But neither glaſs nor ſtone-ware veſſels can reſiſt the immediate action of a fire, becauſe they are apt to crack, as well by being expoſed to the current of cold air

which paſſes through the furnace, as alſo in conſequence of the cold, which is occaſioned whenever freſh coals are laid on the fire. For this reaſon they ought to be coated with a kind of luting, before they are put into the furnace. For this purpoſe, many kinds of coatings have been invented, ſome of which are attended with too much trouble, while others are too expenſive; and at laſt, do but the ſame ſervice upon the whole. The following extremely ſimple and cheap coating, has hitherto conſtantly anſwered every purpoſe, as well as I could wiſh. I mix two parts of common loam with one of clay, and after letting it lie in water till it is thoroughly ſoftened, add to it a little calves hair or chopped flax; then mixing the whole very well together, coat thoſe veſſels with it, which are to be expoſed to the naked fire. If, after the coating is dry, I diſcover ſome trifling cracks in it, I coat the veſſel over once more very thinly with the ſame materials, by which means all theſe little cracks are filled up. When the coating is required to be of a fuſible nature, one part of very clean ſand and a fourth part of litharge, may be added to the mixture.

The ſame kind of coating may be employed alſo on thoſe furnaces which are made of iron. If it be thought proper, one part of ſand or elſe of brick-duſt, may be added to it.

Laſtly, it remains to ſpeak of the *cements* which are uſed for glaſs or porcelain-veſſels that are broken. For the former, I have found the following to anſwer extremely well, viz: of minium or elſe litharge, quicklime and brick-duſt, equal meaſures are reduced to as fine a powder as poſſible, and made into a ſtiff paſte with painters varniſh: but it muſt be obſerved, that a ſufficient time after the application muſt be allowed it for drying, till it grows as hard as ſtone. For the latter, let quick-lime, rubbed down to as fine a powder as poſſible, be worked up with white of eggs or cheeſe-curds, to the conſiſtence of dough. This ought to be applied with the utmoſt expedition, as otherwiſe it will be apt to grow hard before it is out of the operator's hands.

## CHAP. V. Of the OPERATIONS of CHEMISTRY.

### SECT. I. THE OPERATIONS CONSIDERED AT LARGE.

THE Inſtruments which have been deſcribed in the preceding Chapter, are uſed agreeably to the different chemical purpoſes which are intended to be attained with bodies. But according to the different application of theſe, the treatment of the bodies likewiſe muſt neceſſarily be different. Theſe various modes of treatment are, in the language of the art, called by the general name of *Operations*, and may be divided into *mechanical* and *chemical* operations.

With a view to avoid prolixity, I ſhall paſs by the *mechanical* operations, (in which either a mere ſeparation of the integrant parts of a body from each other, or a mere aggregation of intire bodies with each other takes place), and confine myſelf to the deſcription of the operations peculiar to Chemiſtry.

*Chemical operations* are ſuch as are performed by the active inſtruments above-mentioned, and are attended with a change in the conſtitution and intimate mixture of bodies, whether this change conſiſts of decompoſition or compoſition, or of both together. The chief operations are: *Diſtillation*, *Sublimation*, *Calcination*, *Fuſion*, *Solution*, *Inſpiſſation*, *Precipitation*, *Cryſtallization* and *Reduction*. All the reſt are only ſpecies of theſe.

In the rank of active inſtruments, fire occupies the firſt and principal place: for this reaſon, in deſcribing the operations, I ſhall begin with thoſe in which fire exhibits its direct and immediate effects. The firſt action of fire upon the much greater part of bodies cauſes the eſcape of the volatile matters in them; as is more particularly obſerved in diſtillation, ſublimation and calcination; after this it effects the liquefaction of bodies, as is ſeen in ſolution, fuſion and vitrification.

*Diſtillation* is an operation, in which by means of fire, the volatile and fluid parts of bodies are elevated in the form of vapors, from the coarſer particles being carried away which are not poſſeſſed of this property in the ſame degree, and pro-

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pelled into another place, where they are condenſed into drops, and by a proper management of, as well as in conſequence of the nature of the veſſels uſed for this purpoſe, collected in appropriate veſſels.

No diſtillation can be performed without fire. This is an inconteſtible truth. Fire conſequently muſt be conſidered here as an active inſtrument of the moſt indiſpenſable neceſſity, and as the actual cauſe of this effect. But firſt we muſt explain in what manner fire operates this determinate effect.

A body, to be fit for diſtillation, muſt be poſſeſſed of volatile parts. The fire which acts through the diſtilling veſſel, ſeparates firſt the volatile from the heavier parts, unites with them, expands them, and by this means converts them into vapour. In this volatilized ſtate they fly off to a cooler place, where they are quitted by the matter of fire, which there eſcapes through the veſſels, upon which the particles, that have been carried aloft, now mutually approach each other, and are condenſed, and at length coaleſcing into drops, are carried down into the receiver.

From this deſcription of the effects which takes place occur in diſtillation, it is evident, that, properly ſpeaking, four different circumſtances follow each other in immediate ſucceſſion, viz: 1. The ſeparation of the volatile from the coarſer and heavier parts: 2. The elevation of the parts ſo ſeparated in the form of vapour: 3. The condenſation of theſe volatilized parts in a cooler place: and 4. The coalition of the ſame into drops.

It is farther to be obſerved, that the two firſt circumſtances are chiefly, and almoſt ſolely, produced by fire. For as fire has the property not only of pervading the interſtices of all bodies whatſoever, but alſo of diminiſhing, and by a continued action, entirely deſtroying their adheſion to each other, it follows, that the bodies ſubjected to diſtillation, which are confined in ſo narrow a ſpace, muſt neceſſarily undergo this change. Conſequently the moſt volatile and moſt moveable parts are eaſily ſeparated by it, from thoſe to which they formerly adhered; and then by their great rarefaction, are rendered lighter than the ſuperincumbent air itſelf in the diſtilling veſſel, as alſo, by the impulſe of the ſame air, carried aloft in the form of vapour. Now that for this, a determinate and conſtant degree of fire ſhould be requiſite, needs no explanation.

Next to fire then, air alſo has a ſhare in this effect; as well that which is contained in the bodies ſubjected to the diſtillation, as alſo the ſuperincumbent air in the empty part of the diſtilling veſſel. In both theſe ſtates the air is rendered active by the great rarefaction cauſed by the fire. The air which is contained

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in the bodies to be diſtilled, contributes by its expanſion to ſeparate the coheſion of the parts; but the ſuperincumbent air in the empty part of the veſſel, is not only rarified by the fire penetrating into it, and carried aloft, but alſo carries other bodies up along with it.

Thus the elevation of the volatile and fluid parts proceeds as well from the ſpecific levity which the fire imparts to the fluids by its union with them, as from the impulſe occaſioned in like manner, as in the ſeparation that took place in the firſt inſtance, by the fire and air in conjunction.

Now from what we have juſt mentioned, ſome circumſtances which occur in diſtillation, may be egregiouſly well explained, and at the ſame time ſerve to confirm the preceding poſitions, viz: As the fluids ſubjected to diſtillation do not all manifeſt the ſame ſpecific gravity, and as the acids of the vegetable, animal and mineral kingdoms, each reſpectively are poſſeſſed of a peculiar gravity; it is eaſy to conceive, that thoſe which poſſeſs a leſs ſpecific gravity muſt be eaſier rarified, and elevated with a ſmaller degree of fire, and that ſooner than thoſe which have a greater ſpecific gravity. This perfectly accords alſo with experience. For the parts of vegetables and animals which conſiſt of volatile compounds, and for that reaſon are not ſo heavy, are elevated more eaſily and by leſs fire, than the parts of mineral ſubſtances. For inſtance, ardent ſpirits, cauſtic ſpirit of ſal ammoniac and æther, which are eaſily rarified, and are lighter than water, are likewiſe elevated ſooner than this by the ſame degree of fire. While, on the contrary, the mineral acid ſpirits, though they riſe ſoon in the beginning, are carried aloft ſlower than water, and for this reaſon require a much greater degree of fire for their diſtillation.

A particular phenomenon occurs alſo in diſtillation, the cauſe of which may be explained by the law we have juſt before laid down. In the diſtillation of acid ſpirits, their phlegm or water paſſes over firſt: but with urinous and ardent ſpirits, it comes over laſt. Now this difference muſt be derived merely and ſolely from the difference of their ſpecific gravities. For it may be eaſily demonſtrated that water is lighter than acids, but heavier than urinous and ardent ſpirits. Now, as thoſe ſubſtances which are lighter than others, muſt neceſſarily evaporate ſooner, the cauſe of theſe different phenomena is eaſily found.

This explanation indeed ſeems to be contradicted by another obſervation, according to which, in the diſtillation of the ſolid parts of animals, the water riſes before the urinous ſpirit, though this ſpirit, as is proved by experiment, is lighter than water. But this phenomenon depends upon a very different cauſe from the former, viz: The animal ſpirits conſiſt chiefly of urinous ſalt; this

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however in the uſual method of preparing them, is commonly produced laſt from the gelatinous compound containing it, (and not till after the decompoſition of this compound) by a very ſtrong fire. For this reaſon, it cannot in the preſent caſe riſe as faſt as the phlegm, which is not nearly ſo cloſely enveloped in the animal compound. The proof of this is, that on a farther diſtillation or rectification of theſe ſpirits, it will abſolutely riſe according to its natural tendency, and paſs over before the water.

A ſubſtance will be the ſooner elevated by fire, the greater the ſurface is, which it preſents to this fluid. For the greater the number of points of contact between that and the fire, the more will this latter be able to act upon it, by which means a ſtronger impulſe is occaſioned, and therefore the riſing of the body muſt be neceſſarily promoted. But, on the other hand, by an increaſe of ſurface alſo, a greater opportunity is given to the evaporable parts of making their eſcape.

A more extenſive ſurface may be given to the bodies which are to be ſubjected to diſtillation, in different ways: 1. By previouſly reducing them to powder: 2. By mixing another fixed body with them, which prevents the re-union of the ſeparated parts: 3. Chiefly by the diſtilling veſſel being made broader than it is high.

The manner in which the particles, which have been raiſed in the form of vapors, unite together and afterwards diſtil in drops into the receiver, is by no means difficult to comprehend. The parts which are thus raiſed in vapor by the intervention of fire united to them, meet together at the upper part of the diſtilling veſſel, and conſequently in a cooler place, where the fire quits the vapors, and makes its eſcape again through the veſſel. At the ſame time, the vapors are condenſed on the interior ſurface of the upper part, where they coaleſce, and, in conſequence of their gravity, ſlide down the ſides into a common channel made in the capital, whence they are carried into the receiver.

Now, in order that theſe drops thus collected may cool as much as poſſible before they come to the receiver, as otherwiſe much would evaporate, it has been contrived in the diſtillation of great quantities, to paſs the tube of the alembic through a tube filled with water, which, for this reaſon, is called a refrigeratory, or cooler. The drops, in gliding down through this tube, which is conſtantly cooled by the ſurrounding water, loſe their heat, and conſequently enter quite cool into the receiver *. For this purpoſe alſo are uſed the Black-a-moor's heads, made mention of at page, 87.

* A very much improved method of cooling diſtilled liquors, is mentioned by Profeſſor *Weigel*, in his Chemico-Mineralogical Obſervations.

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The fire may be introduced either directly or indirectly into the veſſels containing the bodies which are to be ſubjected to diſtillation. The veſſels adapted to this operation, are either cucurbits, matraſſes, or retorts; of which the former are put ſet in a peculiar furnace, called the diſtilling furnace: but the latter, either in a ſand or water-bath, or elſe they are expoſed to a naked fire in the reverberatory furnace.

As well the veſſels as alſo the mode of diſtillation, muſt be ſelected according to the variety of the materials which are to be diſtilled. Very ſubtle, fine and volatile bodies, ſuch as ardent and urinous ſpirits, ethereal oils and waters, which will riſe with a gentle degree of heat, are commonly diſtilled in matraſſes and cucurbits. The more heavy ſubſtances, however, which require a more intenſe, nay the moſt intenſe degree of heat for their expulſion, and conſequently do not riſe ſo eaſily into the capitals, as the former; empyreumatic oils, for inſtance, and mineral acid ſpirits, which muſt be expelled by a fierce fire, cannot be diſtilled more conveniently than in retorts. Upon the whole, as in moſt caſes, matraſſes as well as retorts, may be uſed for all volatile ſpirits. It is, however, more advantageous to employ retorts for theſe latter; becauſe there is but one juncture to be ſecured in retorts; whereas in matraſſes, on the contrary, there are two junctures to be ſecured, conſequently with the latter veſſels, a greater loſs from evaporation is to be expected, during the operation.

According to the difference of the diſtilling veſſels which are made choice of, the diſtillation bears a different name. The diſtillation which is performed in cucurbits, matraſſes and retorts, is called *diſtillatio per aſcenſum*, becauſe in it, an elevation of the vapors neceſſarily takes place. Next to this, there is another method, which was chiefly followed in ancient times, and is called *diſtillatio per deſcenſum*; which however is no longer uſed at preſent; becauſe the liquors obtained this way, have, inevitably, an offenſive ſmell. Indeed, this mode was practiſed no longer than while the former was unknown.

The former of theſe methods, moreover, may be ſubdivided into *dry* and *humid diſtillation*; becauſe by both, as well from vegetable as from animal ſubſtances, very different juices are obtained. It is called *dry diſtillation*, when ſolid and dry bodies are incloſed in diſtilling veſſels by themſelves, and treated with fire without the addition of any fluid, by which conſequently thoſe fluids only, that are contained in them, are forcibly expelled. In this manner are obtained from mineral ſalts, the mineral acids, and from the parts of animals and plants, empyreumatic ſpirits, oils and volatile ſalts. *Humid diſtillation* is, when to the ſub-

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ſtance which is to be diſtilled, there is added a watery or inflammable fluid, which during the diſtillation comes over the helm again impregnated with other volatile particles. For the dry diſtillation, a ſtronger fire, as is very obvious, muſt always be employed than for the humid; for this reaſon alſo, it is more convenient to uſe a retort for the former, becauſe in this, there is no occaſion for the vapors to riſe ſo high.

Of the two kinds of diſtillation mentioned above, that *per deſcenſum*, is the moſt ancient: for no trace of a diſtillatio per aſcenſum is to be found, either in *Pliny* or in *Dioſcorides*, or in any other writer of the firſt centuries: conſequently it may be affirmed with certainty, that in thoſe times, it was not yet known. Both thoſe ancient authors only deſcribe the apparatus, by which the Egyptians extracted from cedar wood a certain oil, which they uſed in the embalming of bodies; and the manner in which they fuſed the pitch, and collected the oil evaporating from it, with wet ſheep-ſkins extended over it, with the fleeces on, whence it was afterwards obtained by wringing them out, and laſtly, ſeparating it from the water. The diſtillatio per aſcenſum, which we now uſe, is conſequently an invention of later times. The firſt account we have of it, is to be found in an ancient Greek author, of the name of *Zoſimus*, who lived in Egypt in the fifth century. In his manuſcript, the matraſſes with their capitals are delineated: but exactly in the ſtate in which they neceſſarily muſt have been at the beginning of their invention, that is to ſay, very imperfect. Figures of theſe utenſils in their more advanced ſtate are to be ſeen in *Borrichius de Herm. et Egypt. Sapientia*, paragr. 156. In the time of *Geber*, the operation was already more known.

It has likewiſe become cuſtomary to give names to the diſtillation, according to the difference of the proceſs, and the views of the operator. It is therefore ſometimes called *Cohobation*, ſometimes *Abſtraction*, at other times *Dephlegmation*, at others *Rectification*. When a diſtilled fluid is poured afreſh upon another ſubſtance of the ſame kind, and drawn off from it again in order to make it more efficacious, this operation is called *Cohobation*. When a fluid has diſſolved another body, and is drawn off again from it, the proceſs bears the name of *Abſtraction*. When, on the contrary, the aqueous parts of a fluid are ſeparated from the ſpirituous, or vice verſâ, this operation, in which generally one of the two parts remains behind in the diſtilling veſſel, is termed *Dephlegmation*; and ſometimes in the former caſe *Concentration*. The intention is nearly the ſame alſo in *Rectification*, which takes

place when the diſtillation of any thing is repeated with a view to obtain it in a ſtate of greater purity.

But when the volatile ſubſtances in different kinds of bodies are neither of a fluid nature themſelves, nor united with any fluid ſubſtances in the bodies which may impart fluidity to them; they are by the action of fire expelled in a concrete ſtate, and in this caſe the operation is called *Sublimation.* Both operations conſequently bear a great reſemblance to each other; both are the effects of the action of fire, and they only differ in this, that in the former, fluids are raiſed; in the latter, ſolids. In both, this effect takes place in the form of vapors, by means of fire.

Fire, the grand material agent of Nature, is in this operation alſo of ſublimation, as in that of diſtillation, the efficient cauſe: nay more, this fluid which penetrates all kinds of veſſels, accompliſhes here every thing of itſelf alone. In order to be convinced that all the effects of fire depend on a real ſubſtantial matter, which pervades the veſſels that are expoſed to the fire, and acts upon the materials contained in them, we only need to conſider attentively the operation of ſublimation. For it is certainly very amazing to ſee the moſt heavy ſubſtances which were at firſt lying at the bottom of a veſſel, by means of a continued degree of heat proportioned to their quantity and gravity, gradually raiſed up from the bottom, and at length hanging on the upper part of the glaſs. It is natural to conclude from hence, that one of theſe heavy bodies has been gradually carried along by ſome other body, in the manner here deſcribed, and depoſited in another place: juſt as a torrent ſweeps heavy ſtones away with it in its courſe, and leaves them in another place, where its violence is diminiſhed. Now as no other ſubſtance can be ſuppoſed to exert this force in ſublimation, than a matter which eſcapes from the fire and pervades the heated veſſels, it muſt neceſſarily be the ſole material cauſe of the whole of this effect.

The ſolid and concrete bodies, which are capable of being raiſed or ſublimed by fire, are either *ſaline*, *ſulphureous*, or *ſemi-metallic* ſubſtances.

Theſe bodies, however, are not only themſelves ſublimable by fire, but are alſo poſſeſſed of the power of carrying aloft with them other leſs volatile bodies, when theſe are united to them. In conſequence of this, ſal ammoniac carries up with it copper, iron, antimony, and ſome other metals. Empyreumatic oils riſe with volatile alkali. Zinc and arſenic carry up even the moſt fixed metals, and unite intimately with them.

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The operation of ſublimation may be performed either in a matraſs of a ſize proportioned to the quantity of the body to be ſublimed, which needs be cloſed with a paper ſtopper only, and upon which ſoon, either a blind, or beaked capital may be ſet; or it may be carried on in a retort, either of glaſs or of earthenware, either plain or tubulated. Retorts are particularly employed in ſuch caſes where a fluid comes over before the actual ſublimation begins; or elſe common phials may be uſed with this intention: ſometimes too, an ordinary earthen pot or jar, covered with a paper cone, will ſerve this purpoſe. Formerly, aludels were made uſe of, which however are now entirely neglected.

The fire ought to be proportioned to the nature of the bodies which are to be ſublimed, as well with regard to their gravity, as alſo to their volatility. Hence ſometimes a gentle, and at other times a fierce fire, will be requiſite, and this may be applied either directly or indirectly. Thus volatile alkali, for inſtance, camphire and ſulphur, require but a gentle heat, being all light bodies; whereas heavy bodies, ſuch as the mixture for making cinnabar, need a much briſker fire. A fire therefore proportionate to the nature of the bodies to be ſublimed, ſhould always be applied; becauſe here the power of the fire muſt produce the whole of the effect.

To take a general view therefore of this ſubject, the ſublimation of bodies fit for undergoing this operation, proceeds in the following manner: they are diſſolved by the power of the fire, converted into vapor, and in this ſtate raiſed by the continued impulſe of the ſame power to the oppoſite and ſuperior, and, conſequently, cooler part of the veſſel, where they adhere, and form a more or leſs ſolid body, according to the peculiar tendency of their natures. All this is ſolely the effect of the fire. For both the veſſels which contain the body ſubjected to ſublimation, and the infinitely ſmall particles of the body itſelf, are penetrated by the elementary matter of fire. Now by this, the natural coheſion, and, conſequently, the ſpecific gravity of the body is very conſiderably diminiſhed, and the ſmalleſt particles of it are inclined to ſeparate from each other, becauſe they loſe their attraction to each other by the fire's inſinuating itſelf between them. In this ſtate are the now looſened ſmall particles even of a body, which in its entire ſtate was heavy, ſeparated from each other by the inceſſant influx of the ſubtle matter of fire, in a ſtream, as it were, from the bottom towards the top of the veſſel, and being converted into vapors, are carried aloft along with it. Thus within the ſubliming veſſel, do theſe atoms, deprived of their former coheſion and gravity, float, as it were, in the matter of fire which pervades the veſſel, in like manner as

other ſimilar atoms are born about inviſibly in any other fluid menſtruum. But in the upper region of the veſſel, where the matter of fire that has ariſen with them uſes to make its eſcape, the elevated atoms which cannot follow it any farther, muſt of neceſſity remain attached to the veſſel's interior ſurface: for as they here part with the matter of fire, they both can and muſt come into contact with and attract each other again, according to the powers naturally inherent in them; and for this reaſon they adhere there, and again form one intire aggregate body.

Subſtances which are obtained in this manner, are diſtinguiſhed in a general way by the name of *Sublimates*; but when they are of a looſe and pulverulent texture, they are particularly called *flowers*.

The object of ſublimation is not always the ſame: ſometimes it is performed with a view to ſeparate what is pure from what is impure; this is the caſe in the ſublimation of ſulphur and of camphire: ſometimes for the ſake of uniting a fixed with a volatile body, as in the preparation of the martial flowers of ſal ammoniac: ſometimes alſo to ſeparate volatile from other fixed ſubſtances with which they are united, as happens in the ſeparation of ſedative ſalt; and laſtly alſo for the purpoſe of uniting together more intimately different volatile bodies, as is done in the preparation of cinnabar and ſublimate mercury.

When a ſolid body is changed to ſuch a degree, that its hardneſs and ſolidity, which are the effects of the ſtrong coheſion of the parts, are deſtroyed by it, and that now it becomes brittle, or is even reduced to powder; whether any of the ſubſtances that are deached from it, be collected or not, this operation, according to the general acceptation of the term, is called *Calcination*.

This change may be produced in the greateſt part of the bodies on the face of the earth; as in metals, earths, ſtones, ſalts, vegetable and animal ſubſtances. And, according to the difference in theſe bodies, as alſo to the different methods of treating them, the operation as well as the altered body, acquire a particular denomination.

The operation may be performed in two different ways: either by fire alone, which ſometimes muſt be ſlow, ſometimes briſk: or by the other active inſtruments, the effect of which conſiſts either in the privation of the conſtituent part which unites the particles of the body together, or of the acceſſion of ſome extraneous particles.

Fire poſſeſſes in a high degree the power of deſtroying the eſſential bond of union in bodies; whether this be of a phlogiſtic nature, as in metallic bodies; or gelatinous as in the parts of animals; or an earthy-oleaginous mucilage, as in vegetables; or

water

water and air, as in different ſalts and ſtones; as alſo, by this means, of changing bodies which formerly were hard and ſolid, to brittle and pulverulent. In this manner all baſe metals, and ſemi-metals are deprived of their metallic appearance: vegetables, and the parts of animals, are in cloſe veſſels converted into coals, and in the open air into aſhes: in like manner, alum and borax, as alſo ſelenite, are burned to powder. In many caſes ſimilar to theſe, fire ſeems to do nothing elſe than put bodies into a calcined ſtate by the mere expulſion of their volatile parts: but in divers inſtances properties are diſcovered in calcined bodies, which cannot be accounted for by the mere loſs of their volatile parts; an inſtance of this is the calcination of quickſilver to a red powder, without the addition of any other body; the preparation of minium or red lead, and the burning of quicklime. In this and various other ſimiliar preparations, we meet with ſuch effects as ſeem to indicate the incorporation of ſome extraneous matter: but as they can have acquired this foreign matter no where elſe but from the fire; no other concluſion can be formed than, that, during their expoſure to the fire, a real ſubſtance has incorporated itſelf with them from the fire, which conſequently muſt be the cauſe of the different new properties exhibited by the body. So that fire cannot in every caſe be conſidered merely as an active inſtrument; ſince we muſt allow that frequently a real ſubſtance is yielded by it, which unites with bodies; and on account of this actual acceſſion of matter, it has a ſhare at the ſame time in the changes produced in bodies, and therefore muſt not be loſt ſight of in the explanation of the new properties of theſe bodies. Nothing proves the truth of this aſſertion ſo well, as the tranſmutation of quickſilver, i. e. mercury in its metallic ſtate to a red powder, by means of fire alone. For here it cannot be ſaid that the converſion of the mercury into a powder depends on the loſs of a certain conſtituent part, becauſe the ſame red powder may without the addition of any extraneous ſubſtance, be changed into quickſilver again, by a briſk fire. Its diviſion into a powder therefore muſt depend merely on a certain extraneous matter which has penetrated into its interſtices, where it remains combined. Beſides this inſtance, the acceſſion of the matter of fire in that other of the burning of lime-ſtone appears very evident by the properties this ſubſtance afterwards requires of corroding and heating.

Calcination, in the proper and more ſtrict ſenſe of the word, is the mere operation of fire upon metallic bodies and calcareous earths, and in the incineration of vegetable and animal ſubſtances. This calcination, therefore, may be diſtinguiſhed by the name

name of *perfect*, from another which is *imperfect*; and which is performed by acrid saline substances of various kinds: or which takes place when certain salts themselves are converted into powder by heat. The products of a perfect calcination are likewise very properly denominated *Calces*, especially when they are of a white colour; but when they are yellow, red or brown, they are generally called *Saffrons* (Croci.) When a metallic substance has been calcined by acrid salts, either dry or liquid, the operation is called a *Corrosion*, but the product of the operation bears the name of *Rust*. *Reverberation* is a mode of calcination, by which the bodies subjected to calcination are struck by the fire from every part. When ores of metals pounded and washed, are exposed to the fire, they are said to be *roasted*, and this kind of calcination is called *Roasting*. *Cementation* is, when metallic substances, in the form of thin plates, are laid in strata together with dry salts, in a crucible or cementing pot, which is furnished with a lid, and set in the midst of red hot charcoal. *Detonation* is an operation, in which nitre is projected into a red hot crucible, together with an inflammable substance or a metallic body abounding in phlogiston. *Decrepitation* takes place almost solely with respect to common salt: at least it is seldom performed with other salts which have the same property of making a crackling noise, when in contact with burning fuel.

In every calcination, some volatile parts are expelled by the fire; even supposing them to be nothing else than phlogiston, air and water. Hence this operation cannot be performed in a vessel perfectly close, and from which there is no possible egress. In every case, the matter that is detached must have an opportunity given it to escape, in default of which, the bursting of the vessel must be expected.

When the cohesion of solid bodies is interrupted by a fluid to such a degree, that this latter by a peculiar action sets their smallest molecules at a distance from each other, they become fluid. In this state the body is formed by the intimate union of the solid with the fluid substance, and is called a *Solution:* the operation, *Solution* likewise: the body to be dissolved, the *Solvend:* and the fluid substance, the *Menstruum* or *Solvent*. When the dissolving substance has taken up as much of the body which is to be dissolved, as agreeable to its nature it can, the solution is said to be *Saturated*.

The operation of *Solution*, therefore, consists in rendering a solid body fluid, by such a close and intimate union with a fluid body, or with any other body which

may eaſily be made fluid, that a perfectly homogeneous tranſparent compound ariſes from it*. This is an effect that depends upon the natural powers of things, and with reſpect to which, an explanation muſt be given, how a body can be divided by another into its ſmalleſt particles, taken up into its interſtices, and there kept impriſoned. For this purpoſe, the following propoſition muſt be admitted as an axiom, viz: that all the viſible bodies in Nature conſiſt of ineffably ſmall molecules, which in each body are of a peculiar kind, and ſo minute, that at the utmoſt extent of their diviſibility they are totally inviſible. Theſe are called *the homogeneous conſtituent parts*, or *the ſmalleſt molecules of bodies*. The greater the quantity of ſuch molecules there is in a body, the larger is its bulk. Now all theſe particles cohere together in each body, by a power with which Nature has been endued by God: and hence ariſe all the ſolid bodies in Nature, which in this ſtate form large, palpable and opaque bodies; and are then capable of preſerving their ſpecific form. The exiſtence of this power, whether it be called the power of *coheſion*, or *attraction*, or *affinity* †, cannot be denied. All theſe appellations denote one and the ſame effect. This effect, in ſhort, is the bond or tie which holds the ſmalleſt molecules of each body together. This power alſo exiſts as well in fluid as in concrete ſolid bodies. Now when a fluid menſtruum, or ſolvent (being likewiſe an aggregate body, compoſed of innumerable homogeneous molecules, which, though they cohere by the virtue of the ſame power, are neverthele ſs in continual motion in conſequence of the fluid ſtate they are in) when this fluid menſtruum is poured upon a ſolvend, either ſolid or fluid, hard or ſoft, it happens, in caſe the ſmalleſt particles of the ſolvent have a ſtronger attraction to the ſmalleſt particles of the ſolvend, than theſe particles themſelves have to each other, that now the particles of the ſolid body will by degrees quit each other, and be obliged by a ſuperior attractive force to unite with the particles of the ſolvent, from which there ariſes a new aggregate, or compound, conſiſting of the ſolvent and the molecules of the ſolvend, held inviſible in it, which compound is now termed a ſolution of the body, with the molecules of which it is united.

* Not only a ſolid body may be the object of ſolution, but even fluid bodies, provided the menſtruum be ſtill more fluid; as eſſential oils, which are ſoluble in ſpirits of wine, water in air, and, in general, liquids in permanent vapors or gaſes. [E]

† In this, M. *Wiegleb* differs from the generality of Philoſophers, who conſider the powers of coheſion as different from, and even in oppoſition to, that of affinity, or elective attraction. [E]

united. But when this power does not exiſt between the ſmalleſt particles of the ſolvent and thoſe of a body, it will be in vain to attempt the actual ſolution of that body. By a *genuine ſolution*, therefore, according to the explanation given above is underſtood, that union alone of two or more bodies by which they are taken up in the ſolvent, and held in it inviſible, inſomuch that the ſolvent remains perfectly tranſparent. On the contrary, when the minute molecules of a body are ſo mixed with a fluid that they may ſtill be perceived by the eye to float in it, and ſooner or later are obliged, in virtue of their ſpecific gravity, to ſink to the bottom, and, conſequently, have not contracted any intimate union with the particles of the fluid: this cannot be called a real ſolution, but only a *mechanical diviſion* or *mixture*.

In every ſolution, three different circumſtances are to be taken into conſideration.

1. The motion of a fluid, by which the ſolution is promoted.

2. The union of both bodies, the menſtruum and the ſolvend.

3. The retention of the diſſolved particles in an inviſible ſtate in the fluid menſtruum.

With regard to the *firſt* circumſtance, it muſt be obſerved that the fluidity of the ſolvent or menſtruum is a condition, without which no ſolution can take place. The motion of it, however, is not abſolutely requiſite; for a fluid ſtanding at reſt is ſometimes obſerved to diſſolve a ſoluble body that has been put into it. The motion of the menſtruum, however, promotes the ſolution. For the particles which from the ſurface of a ſolvend have juſt united with the menſtruum or ſolvent, cannot without motion be diffuſed through the whole of the ſolvent, and, conſequently, are united to its lower ſtratum only; and thus render this part of the ſolvent heavier than the other yet unſaturated part; which heavier part, therefore, in conſequence of its weight lying undermoſt, immediately covers the ſolvend, and thus prevents the unſaturated remainder from acting farther upon it. So that if the lower ſtratum of the ſolvent which is ſaturated with the ſolvend, were not by ſome motion imparted to it, removed from its place, the reſt of the ſolvent could not unite in like manner with the remaining parts of the ſolvend; hence it would follow of courſe, that the ſolution of the whole body could not proceed, but muſt ceaſe after the firſt impetus is over. When therefore motion is produced in the ſolvent, the ſolution of the mixture is likewiſe promoted. And this is the reaſon why the ſolution is facilitated, and the ſooner accompliſhed by heat, which promotes the motion of fluids, as likewiſe by ſtirring or otherwiſe

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agitating it. Finally, if the ſolvent body has no fluidity of its own, it is neceſſary that this quality ſhould be imparted to it; for, without fluidity, all homogeneous parts are immoveable; and yet without motion, they cannot act upon other bodies: thus no ſolution can be effected without fluidity. The *ſecond* circumſtance, viz: The union of the ſolvent with the ſolvend, is the principal object in every ſolution, and therefore very worthy of attention: ſince by this only, a ſolution is known to be genuine. Every thing here depends on the attraction of the ſmalleſt particles of the menſtruum with the ſmalleſt particles of the ſolvend, and vice versâ. In theſe caſes this attraction muſt neceſſarily be ſtronger than that which the particles of the ſolvent, as well as thoſe of the ſolvend, have among themſelves. The *third* circumſtance, viz: the retention of the diſſolved particles in the fluid menſtruum, and that the diſſolved bodies, which, previous to the ſolution, poſſeſſed a determinate ſpecific gravity, are nevertheleſs after it ſuſtained inviſibly floating in the ſolvent, is an effect of the ſecond circumſtance, viz: of the mutual attraction of the ſmalleſt particles of both bodies. The *third* circumſtance again ſeems to depend upon *three different* cauſes. And *firſt*, upon this: that the particles both of the ſolvent and of the ſolvend, which combine together in the ſolution, are extremely ſmall. For though theſe bodies may be of a compound nature, and in their preſent ſtate of aggregation form a groſs viſible body; nevertheleſs each molecule, or homogeneous particle of the viſible body, taken by itſelf, is unutterably ſmall, ſo that it can no longer be diſcerned by the naked eye, and, conſequently, is in this ſtate likewiſe very light. Hence, ſetting aſide even the mutual attraction of the particles, each of theſe particles, on account of its being lighter than the ſolvent, may be ſuſtained floating in it. The infinite ſmallneſs of the ſimilar or homogeneous particles may be demonſtrated and evinced, even by the ſolution of them: ſince groſs, earthy, and opaque bodies, ſuch as chalk, lime-ſtone, and metals, when diſſolved in their proper menſtrua, appear as clear and tranſparent as water. Of the ſame tenuity and levity likewiſe, are the ultimate particles of gold, the heavieſt body in Nature: the utmoſt term of their diviſibility being only when they are united with the acido-ſaline particles of aqua regia, and ſwim about in it inviſible. *Secondly*, the retention of the particles of the diſſolved body, ſeems alſo to proceed from the *fluid ſtate and mobility of the menſtruum* by means of which, the diſſolved particles, now ſeparated from each other, are kept in continual motion, and even at a diſtance from each other, and are prevented from reuniting by the intervening particles of the fluid. But as ſoon as the menſtruum flies off, theſe particles immediately coaleſce

into larger masses, and acquiring by this means greater gravity, fall to the bottom. But, *thirdly*, the reciprocal attraction of the parts on which the whole of solution depends, is also the particular and chief efficient cause of this circumstance; and without this, the fluid, notwithstanding its mobility, would never be able to sustain the molecules: without this, from the two substances which compose a solution, nothing but a mere mechanical division can arise. The attraction therefore which the particles of the solvent have to the particles of the solvend, must be stronger than the attraction by which these particles, previous to the solution, cohered with each other; and for this reason, when they have once contracted an union with the former, they must necessarily cease to fall to the bottom of the vessel spontaneously, being prevented from so doing by the abovementioned power. Neither would it, if this power did not exist, be in the least conceivable, why these particles, even were they as light and as small again as they are, should not in process of time separate from the fluid and fall to the bottom of the vessel. Certainly, either this must be the case, or it must be admitted, that the smallest particles of bodies have no gravity at all. But if they had not gravity, I should be glad to know whence, in the case of an alkali, or even of certain other metals being poured into a metallic solution, the gravity of the particles proceeds, by which all the dissolved atoms precipitate to the bottom at once. Hence, therefore, it is evident, that even the smallest atoms preserve, during their solution, their specific gravity, which gravity, however, they cannot exhibit in this state. But on account of their extreme minuteness, and the mobility of the menstruum, it is the more comprehensible, that in consequence of the force of attraction, or the combining power being superadded to these conditions, the abovementioned atoms are retained by the particles of the solution, and remain united to them, till some other body intervenes which weakens this combining power, either in consequence of its possessing a greater power of combination with the smallest particles of the menstruum than the dissolved body does; or of its power of combination with the dissolved body being stronger than that of the menstruum with the same body. In both cases the former union is destroyed. The dissolved parts now cease to be sustained; they become visible, and fall to the bottom.

The solution of bodies is effected either in the *humid* or *dry* way.

A body is dissolved, viâ siccâ, or in the *dry way*, either when fire itself constitutes the menstruum of it, or when a solid menstruum must first be brought into a fluid state by fire, before it will act upon the solvend for this purpose, and bring it into a similar state of fluidity.

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The former of these two modes of solution, viâ siccâ, is otherwise by chemists commonly called *Fusion*. By this is always meant that operation in which solid and hard bodies are brought into a fluid state, merely by means of fire. For very substantial reasons, I have arranged it under the head of Solution.

Fusion is the liquefaction of hard and solid bodies by means of fire. But no solid body can be brought into a fluid state, otherwise than as another substance, which is fluid, destroys the combining power of the smallest homogeneous parts of such body, and separates these parts from each other. Now as long as a body, in consequence of its cohesion with an extraneous fluid substance, continues to be excluded from the previous firm cohesion of all its parts, it is called a fluid body. But as various as the extraneous fluid is, by which the solid body has been converted into a body, in like manner fluid, so varied will this latter also be found in its phenomena and effects. Pursuant to this idea, a certain coincidence may be discovered between the fusion of a body in fire, and the solution of a body in like manner solid, by other fluid menstrua; and when both effects are duly considered, we find, that as distant as they seem at first sight to be from each other, they depend however, in fact, upon the same cause; they may consequently also both be very properly brought under the same point of view. Now it being admitted as an undeniable fact, that no solid body can be reduced to a fluid state, without the intervention of a fluid substance: and, on the other hand, that solid bodies become fluid in the fire, this fluidity, by consequence, ought to be solely ascribed to the matter of fire which penetrates them copiously, because no other substance can have any share in producing this effect. Accordingly, when a solid body, whether it be a metal, or a fusible stone, is exposed to the fire in a less fusible vessel, it may suffer the action of fire for a long time, (which, however, is longer or shorter, according to the peculiar nature of the body) and still remain unaltered; except that it will acquire the property of shining from the fire. But when the intensity of the fire ab extra is increased more and more, the luminous or red-hot state of the body is seen to increase also; and when at last the fire is raised to a certain height, which height differs with respect to almost every substance, the body, which was before hard and solid, is now observed to melt or fuse, and to continue in this state as long as the fire remains at the same height; and, in this state, it is called a fused or melted body. Consequently, a solid body, thus exposed to the fire, must of necessity be entirely filled with that all-penetrating matter: when this has taken place in a body, in as great quantity, as from its nature it is able to retain, and all its homogeneous atoms are surrounded with the

matter of fire to ſuch a degree, as to loſe their mutual attractive powers, they become moveable, and in conſequence of the intimate union they have formed with the matter of fire which ſurrounds them, are carried to and fro in all directions; thus forming a red-hot body in a ſtate of fuſion. A body therefore in a ſtate of fuſion, is, in my opinion, nothing elſe than a body diſſolved by the ſimple matter of fire alone, whoſe ſmalleſt atoms float about in this igneous matter, in the ſame manner as in a menſtruum.

No one has hitherto been able to fuſe all bodies indiſcriminately, by means of fire alone: though it is very probable that fire is capable of producing this effect. The difficulty ſeems, as has been ſaid elſewhere, to lie in this, that we cannot increaſe the fire in the proportion requiſite for each body. The following ſubſtances are fuſible by themſelves without addition: All compound earths; all metals; the fixed neutral ſalts indiſcriminately; the fixed alkaline ſalts, ſulphur, reſins, and all unctuous bodies.

The metals, in general, deſerve the greateſt attention of any, not only becauſe they melt by very different degrees of heat, but alſo becauſe they exhibit at the ſame time ſeveral other very remarkable phenomena.

For inſtance, with reſpect to the fuſion of metals, if we obſerve the point at which they begin to melt, we ſhall find, that lead and tin melt before they are red-hot; ſilver and gold, in a ſtrong heat: but copper, and braſs which is made of copper, not till they have continued for a long time in a bright red heat, of which latter metals however, braſs melts ſooner than copper. Iron requires the fierceſt and longeſt continued fire of all for its fuſion: but platina is the moſt refractory.

When into melted gold, ſilver, copper, lead, tin or zinc, a piece of the ſame metal is put, it ſinks to the bottom. The ſame metals alſo occupy, when in a ſtate of fuſion, a greater ſpace than before: and this expanſion ſeems to conſtitute the firſt degree of their fluidity. When upon this they are poured out in a certain form, they loſe again in cooling the former increaſe of their bulk; as plainly appears by the concavity of their ſurfaces. From theſe experiments it is inferred that the abovementioned metals increaſe in bulk during their fuſion, but at the ſame time loſe ſomewhat of their ſpecific gravity.

The ſame phenomena are exhibited by tallow and wax; ſince theſe bodies during fuſion increaſe in bulk, and ſuffer diminution with reſpect to their ſpecific gravity.

The contrary circumſtance takes place with reſpect to iron, biſmuth, antimony and ſulphur. For theſe ſubſtances, when in a ſtate of fuſion, bear up on

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their refpective furfaces, whole and unfufed pieces of the fame bodies, and do not fuffer them to fink to the bottom; in this ftate confequently they are endued with greater gravity. With refpect to iron too, it is a generally known fact, that when it is poured into the mould, not only no cavity appears on its furface after cooling, as there does on thofe of other metals; but that on the contrary, it expands to a greater fize than it had before; and hence it does not only fwell into every part of the mould, and run over the brim of it, but even burfts it afunder: whereas, the other metals never properly fill up the mould in which they are caft.

The fecond mode of folution in the dry way, is, when certain bodies which cannot be brought to fufion by themfelves, are yet fufed by the intervention of other folid bodies, more fufible than themfelves. To this clafs belong moft of the calces of the bafe metals and femi-metals; which in the fame degree of heat, that they have already fuftained, continue unchanged in the fire when expofed to it without any addition: but when a phlogiftic body, or alkaline falts and certain kinds of earths are added to them, become fufible. As little do the pure vitrefcent and argillaceous earths fufe by themfelves, but muft be mixed with alkaline falts, borax, calcareous earths, magnefia, minium or litharge. In all thefe cafes, however, a continued and violent fire of feveral hours duration is requifite for the fufion of the fubftances, and is likewife the chief active folvent here.

Upon thefe latter cafes depends *Vitrification*. By this is underftood a fpecies of fufion of certain earthy fubftances, any of which are by this means changed into a brittle, extremely refplendent, tranfparent, and perfectly homogeneous body, infoluble in water, called *Glafs*.

Though there are bodies which may be converted into glafs on being fufed by themfelves, and without any addition; yet no glafs fit for ufe can ever be made of one fingle pure fubftance. All glafs that is adapted to common ufe, muft be prepared by the fufion of materials of various kinds together.

The materials commonly ufed for the making of glafs confift in general of earthy bodies, or of fand or white flints calcined and pounded, and a fixed alkaline falt; for which latter, fometimes common pot-afh, fometimes foda, and at other times even mere wood-afhes are ufed. From the afhes of hard woods glafs contracts a brown or greenifh colour, which kind of glafs is ufed for making the ordinary bottles. The cleareft and moft tranfparent glafs is made of pure fixed alkali, and pure colourlefs quartzofe fand; or, alfo by the addition of arfenic, or of a little chalk. When to the vitreous mixture, called *Frit*, various

metallic calces are added, it will form colourless glass, of which are made artificial precious stones.

Though this inestimable production of the fire is very well known and extremely common, the manner in which it is produced is nevertheless highly worthy of our admiration. Of opaque earths, sand, or stones, is formed a substance, called glass; a substance ductile in the fire, but in the cold, hard and transparent. But as these earths and stones which by themselves fuse with so much difficulty, either do not fuse at all in part, or else do not become sufficiently fluid for the purpose; substances more fusible which wholly unite with them, and are not contrary to the end proposed, must be added to them in order to promote their fusion. It appears to me that similar additions exhibit a two-fold effect. First, on account of their being of themselves more fusible, they bring the refractory body into fusion along with them. Secondly, as they act the part of a solvent with regard to the refractory body. Now in like manner as these bodies of easier fusibility are first dissolved by fire themselves, they farther produce, when combined with the matter of fire, the same effect upon the otherwise unfusible body, as nitrous acid combined with water in the form of a weak aquafortis comparatively produces upon crude calcareous earth. According to the natural degrees of affinity, a separation here takes place between the homogeneous parts of the refractory body, and afterwards a fresh and reciprocal union of all the parts of both bodies with each other, and during this, the body fuses to glass. In this transformation or melioration of the earths abovementioned, the simple elementary matter of fire seems to have also a very considerable and essential share. For it is certain, that in fusion, the pure matter of fire not only constitutes the true fluid menstruum; but it is even probable besides, that a certain part of its essence intimately unites with the glass, and that upon this the actual vitrification of the body depends; so that for this reason, in all glass, the matter of fire incorporated in it ought to be taken into consideration*.

As the parts of glass are very hard and rigid, and as we know by experience, that after fusion it is very apt to fly or crack when it is cooled too fast; to avoid this inconvenvenience, all glass, as soon as ever it has received the shape it is designed to have, should be transferred into another commodious furnace, which must be likewise heated, which is called the *annealing* furnace, and there kept for

* The author here, as well as in other parts of the work, speaks in rather too peremptory and dogmatical a stile, on a subject which at best is but uncertain: if not demonstrably false. The assistance of fire need not be called in to account for the union of heterogeneous bodies: their innate power of mutual attraction suffices.

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a certain time in a gentle degree of heat; and, laftly, it fhould alfo cool in it entirely and by degrees. This inconvenient property of glafs, together withits caufe, is eafily explained on the ground of the idea which we gave of vitrification. When we only confider how extremely replete with the matter of fire glafs is, when in a ftate of fufion, and at the fame time how thick and tough it fufes, and how greatly the veffels, formed of it, contract their furfaces when rapidly cooled; and how foon they harden and grow ftiff: it becomes very probable, that on this occafion, a great quantity of elaftic matter of fire muft be enclofed between the interftices of the glafs. Now nothing is fo obvious as, that in this ftate, the matter of fire thus enclofed will be excited by a frefh application of heat, by concuffion, or any other occafional caufe, to expand agreeably to the elafticity of its nature, and by this means caufe the glaffes to fly or crack without any great external violence being offered them. But when, immediately after the glafs has had its proper fhape given it, it is kept for fome time longer in another well-heated furnace, where it may cool gradually: the too rapid induration of its furface is prevented, all the matter of fire contained between its interftices expelled, and thus the glafs is exempted from the inconveniences abovementioned, and rendered fit for ufe and durable.

The folution of bodies in the *humid* way, is effected by various menftrua, which are already in a fluid ftate: as by *air*, *water*, *oils*, *ardent fpirits*, *acid fpirits*, *dulcified acid fpirits*, *urinous fpirits*, and various kinds of *watery folutions of falts*. Thefe may be diftributed into three claffes.

The *air*, which together with water, conftitues the *firft* Clafs, is to be confidered as one of the greateft folvents or menftrua in Nature. Like other folvents, it is endowed with a proportionable power of attraction towards a great number of fubftances. The water which rifes into the air in the form of vapors, is actually diffolved by it, and carried aloft by it in the ftate of a diffolved body. It poffeffes a great power of diffolving the phlogifton which efcapes in a very multifarious manner from terreftrial bodies, in confequence of which they are varioufly changed in their natures. All vapors and exhalations proceeding from the earth, and from the bodies contained on its furface, retire by the power of the elaftic matters which are united with them, to a diftance from thefe bodies; when they are diffolved by the air, and born away, to the great benefit of the animal creation. It muft therefore be imagined that all evaporating bodies themfelves contain a great quantity of air, and of elaftic igneous particles befides, whofe activity is checked by a contrary power, the power by which they are united to each other.

Now theſe, as ſoon as they are rendered active and put into motion, either by heat applied externally, or by other cauſes, will endeavour to ſeparate from each other. This tendency is ſtill more facilitated by the air, by which all bodies are encompaſſed; as it has an attraction to the moſt minute particles or atoms of theſe bodies, and is able to take them up into its own ſubſtance. Conſequently, all the vapors proceeding from the earth, and from the bodies on the earth, in virtue of the diſſolving power of the air, mount aloft with it, on which occaſion, this latter element, and the matter of fire which conſtantly accompanies it, act in the ſame manner as other ſolvents do. Thus air properly belongs to the *firſt* Claſs of the ſimple ſolvents.

*Water* is the menſtruum of all ſalts, gums, and ſoaps, of mucilage, arſenic, and other ſaline compounds. Experience ſhews us with reſpect to this ſimple ſolvent, water, 1. That deprived of all its heat it is able to diſſolve nothing: 2. That common water ſerves merely for a conductor to the matter of fire which unites with it, and is the cauſe of the degree of heat it poſſeſſes. 3. That the diſſolving power of common water is always proportioned to the quantity of the matter of fire contained in it. 4. That when it ceaſes to be heated ab extra, it gradually loſes all its heat again, and no more of it remains than what is poſſeſſed by the ſurrounding air; and then the diſſolving power of the water is in proportion to this degree of heat. But when in winter, the air loſes its heat till its temperature is below the 33d degree, water loſes likewiſe all its diſſolving power in proportion as it approaches to this degree. The diſſolving power of water conſequently is always proportioned to the degree of heat which is communicated to it. When water comes to boil, its heat has ariſen to the 112th degree, and this is the higheſt degree of heat it is ſuſceptible of. Any farther heat that ſhould be applied to it, in paſſing through the water, expands it, converts it into vapor, and in this ſtate, carrying it aloft diffuſes itſelf along with it in the air, which diſſolves them both together. But when water can be prevented from evaporating, and be made to endure the fire, a greater degree of heat may be imparted to it, and in this caſe, it can alſo go beyond the natural limits of its diſſolving power, as appears by the experiments made with Papin's digeſtor. In theſe experiments the water cannot make its eſcape, and, conſequently, muſt admit continually more and more of the matter of fire that pervades the veſſel, and thus be heated to a greater degree than it would have been otherwiſe; whence alſo it penetrates ſo forcibly into the horns, nails, and bones of animals, that in a few minutes they are found to be entirely diſſolved, their earthy parts only excepted. All this ſufficiently proves that,

that, properly ſpeaking, it is merely on the fire, which is united to the water, that depends the ſolution of bodies, and that the water here merely ſerves to take up the diſſolved particles, and to diſtribute them equably throughout its whole volume, which muſt be proportionate to the quantity of particles it is intended to take up. It has been obſerved before, that the ſolution of bodies in general conſiſts in a certain power of the menſtruum to combine with the ſolvend; but it did not appear till now upon what this power is founded, or from what matter it actually originates. For every active power always preſuppoſes a matter endowed with ſuch a power. It muſt not, therefore, be conſidered as a contradiction, when it is here affirmed that the matter of fire diſſolves bodies; whereas it was aſſerted before, that the ſolution depended on a certain combining power. There is a cloſe and exact connection and accord between both ideas. In the former the effect only was deſcribed; but here the active principle is determined, and called by its right name. The matter of fire conſequently is the actual cauſe and origin of all ſolutions; on it depends all the combining power of the menſtruum with the particles of the ſolvend; it is the medium which combines both; and conſequently it animates, as it were, and gives life to every menſtruum whatever.---Air and water conſtitute the firſt claſs of menſtrua, in which the matter of fire effects, by means of both, to which it is united, the ſolution of thoſe bodies, whoſe particles do not firmly cohere together. In this claſs, the fire, which is communicated to the water ab extra, is perfectly ſimple, without any other ſubſtance whatever making part of, or being combined with it.

The *ſecond claſs* of *Menſtrua* is compoſed of oils and ardent ſpirits. Theſe are bodies, in which the matter of fire is, by a natural combination of a peculiar kind, united with air and water, in the form of an oily inflammable compound. The ſimpler ſuch a compound is, the fitter alſo it is found to be for the ſolution of other bodies. Hence, too, vinous ſpirits are ſuperior to oils in this reſpect, becauſe the latter contain more earthy particles in their compoſition. In vinous ſpirits, common water again is the baſis, in which is enveloped phlogiſton combined with an acid, and which, after having, by means of heat applied externally, penetrated thoſe bodies, which otherwiſe cannot be penetrated by the menſtrua of the firſt claſs, in which there exiſts only the matter of fire combined with air or water; having, I ſay, penetrated theſe bodies, ſeparates the parts of theſe bodies from each other, and diſſolves them. Though the effects of this ſecond claſs do not in general extend beyond the ſolution of vegetables and

their parts, whence alſo theſe menſtrua chiefly derive their origin, their powers are however in ſome meaſure ſuperior to thoſe of the former, becauſe the ſubſtances that belong to this claſs, penetrate and diſſolve the reſinous bodies, which the former were not able to do. The water ſerves here in like manner to contain the matter of fire, with this difference, however, that here the matter of fire, accompanied with ſome other principles, has been united by nature in the moſt intimate manner to the water.

To the *third claſs* belong in general all *ſaline* menſtrua. The power of theſe is incomparably greater than that of both the other claſſes; particularly the acid ſort, of all other the moſt active. Theſe belong to the ſimple natural mixtures, and cannot be imitated by art. On this account, I am of opinion that their internal compoſition will always remain a ſecret to us; and indeed we might eſteem ourſelves ſufficiently fortunate could we but extend the knowledge of their properties and effects upon other bodies a little farther, and learn how to apply them to advantage. Here, however, are placed the boundaries; here is the *ne plus ultra* of the art. But our natural propenſity to inveſtigation continually prompts us to penetrate ſtill farther, and makes us deſirous of knowing of what theſe ſimple ſubſtances are compounded, and upon what their active powers depend. All experiments, therefore, which are inſtituted for this purpoſe, ought to be conſidered with a retroſpective view, and in ſuch caſes we muſt be contented with mere probabilities; as it is not very likely that we ſhall ever be able to make any farther progreſs in the inveſtigation. If, therefore, we wiſh to acquire ſome idea of the origin of the acids, theſe ſo powerful ſolvents, it appears to me, that we ſhould derive it from the ſimilarity of their effects with thoſe of other bodies. Now ſince we ſee in the operation of fuſion, that the hardeſt bodies, by the matter of fire penetrating them, loſe their former ſtate of immobility and ſolidity, and become moveable and fluid; ſince we know, that mere water when it is coldeſt, or at the time when it contains the leaſt of the matter of fire, alſo diſſolves leaſt; but the more it is heated, that is, the more replete it is with the matter of fire, the more of other bodies it will take up: ſince moreover we obſerve that water, as being the chief conſtituent part of ſpirit of wine and all oils, acquires likewiſe, accordingly as it is differently combined by nature with the matter of fire, different and extraordinary diſſolving powers: it ſeems to be extremely probable that the very great diſſolving power of acids, has its foundation upon this very

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active matter, viz. the matter of fire. Therefore, with *Hierne* *, *Eller* †, *Beaumé* ‡, and others, I derive the origin of all the native ſimple acids from a ſpecies of combination (inimitable by us, and attainable by nature alone) of the ſimple and univerſal elementary matter of fire with air and water, perhaps alſo with various particular kinds of earths adapted to this purpoſe; and, reaſoning from analogy, I am apt to believe, that from this combination, on account of the particular modification and abundant concentration of the matter of fire, ſuch ſolvents are formed, as the hardeſt bodies in nature muſt yield to. All this makes it more than probable, that *the elementary matter of fire is the ſole univerſal menſtruum or ſolvent in nature*; that the whole of the ſolvent power, as well of plain water as of the other ſpiritous, oleaginous and ſaline menſtrua, is derived merely from the matter of fire, which is preſent in them; and that the exceedingly ſmall and unalterable particles of common water only ſerve by way of a ſheath or cover, to afford it an opportunity of manifeſting its diſſolving power upon all bodies, that are capable of undergoing this change.

Laſtly, with reſpect to Solution, this circumſtance is to be taken into conſideration; that not all bodies can be diſſolved by the ſame menſtruum, but that each menſtruum has the property of diſſolving certain bodies only. Here we cannot deny, that the human intellect is incapable of penetrating into the interior receſſes of Nature, and of wholly explaining her ſecret operations. For this reaſon too, in many caſes of natural philoſophy and chemiſtry, we cannot arrive at any thing more than mere probabilities; and it will ever continue to be impoſſible to give a final and determinate anſwer to every query that can be propoſed on this ſubject. What I think I underſtand of it will be mentioned when I come to treat of Chemical Affinities.

*Deliqueſcence* is nothing more than a mere ſolution, and has obtained only a different appellation, on account of its being differently performed. It takes place in ſalts of eaſy ſolution, or in ſaline compounds, and is indeed effected merely by the water contained in the air, which is attracted by that body on being expoſed to a humid atmoſphere.

To this operation alſo muſt be referred *Amalgamation*. By this is underſtood a combination of various metals with mercury, a body, which is generally in

* Acta. Chem. Holm. cum Annot. Wallerii. Holmiæ, 1753. P. I. cap. 6.

† Tractatus Phyſico-Chymici. P. 271.

‡ Chymie Experimentale et raiſonnée. Paris, 1773. Tom. I. p.

a fluid ſtate, whence ariſes a reſplendent, white, ſoft maſs, called an *Amalgama*.

But when a body is not entirely diſſolved by a fluid, which is poured upon it, as is the caſe in a perfect ſolution, but only certain conſtituent parts of it, while the others are left behind, without being farther acted upon by the fluid, the operation is then called an *Extraction*. The nature of the extracted parts is alſo different in this operation, according to the nature of the ſolvent or menſtruum.

*Fermentation* is a true ſolution, but of a very peculiar kind, and which borders very nearly upon Extraction. This operation conſiſts of a viſible inteſtine motion incidental to various bodies, when brought into a liquid ſtate, and manifeſting itſelf by the generation of bubbles of air, and the eſcape of a ſharp pungent vapour. But it is, in fact, the gradual evolution of a body by its own natural powers, which body conſiſts of certain heterogeneous parts blended together, the tendency of this evolution of the body being to ſeparate its various heterogeneous parts, in conſequence of which ſeparation the whole of the body is deſtroyed, and cannot be regenerated from the parts ſo ſeparated.

All organized bodies in general, but more eſpecially fruits, the different ſorts of corn, and all the parts of animals, being ſubſtances which conſiſt of heterogeneous parts, are peculiarly adapted to this operation. The moſt neceſſary condition under which the fermentation is excited in theſe bodies is, that they ſhould be covered with water, or a watery infuſion drawn from them, or in any other way put into a fluid ſtate. In conſequence of this, by a continued gentle heat, an internal motion muſt neceſſarily be produced, which motion ariſes from the different heterogeneous parts, ſome of which are naturally diſpoſed to burſt forth from their former combination, and liberate themſelves on the firſt opportunity.

Air and the matter of fire are preſent in great abundance in the compoſition of theſe bodies, being preciſely the very ſubſtances, from which ariſes the internal motion above mentioned, as they are developed by degrees, and make their way through the fluid. As all fermentation, therefore, is founded upon the eſcape of theſe parts, no fermentation can be brought about in a perfectly cloſe veſſel, from which their egreſs into the open air is impoſſible. In proportion, however, as theſe parts make their eſcape into the open air, other ſubſtances beſides are ſeparated from each other, in the fluid that remains behind.

According to the difference of the compoſition in one of theſe bodies, which have been ſubjected to fermentation, there will be a difference likewiſe in the

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effect. But according to the difference of the effect, the operation obtains a particular epithet. Hence we have the *spirituous*, *acid*, and *putrid* fermentation.

When an ardent spirit is contained in the composition of a body, it is immediately at the beginninig of the fermentation developed from the other parts combined with it, and afterwards extricated, and made fit for an absolute separation. Hence the first stage of fermentation in such bodies, when completed, is called the *Spirituous* Fermentation.

But as in all these bodies, besides the ardent spirit, there is an acido-saline mucilaginous compound, which is not developed in the first stage of fermentation; another separation takes place in the same compound, whether the developed ardent spirit be separated from it or not, after the first period is completed, which proceeds in a very different manner, without any bubbles of air rising to the surface, and without any perceptible motion in the fluid, the escape of a volatile elastic vapor only being observed: it being, in fact, in consequence of the escape of this vapor that the acid contained in the above-mentioned saline mucilaginous compound is developed. During this period, which is caled the *Acid* Fermentation, the ardent spirit, if it has not been previously separated, makes its escape into the air.

When in this manner at length both the ardent spirit and the acid have been developed, there still remains behind a grosser mucilaginous compound, which has not yet been acted upon in the two preceding stages. Now in this same compound, when the solvent power, which still continues, is not put a stop to, by preventing the access of the open air, the last separation finally takes place, which separation is, in fact, a total decomposition and destruction of that part of the compound that still remained behind, and was the most tenacious of all. This last period is called the *putrid* fermentation, or, in one word, *putrefaction*, which is attended with a disagreeable smell. By this the whole cohesion of the organized bodies subjected to it is destroyed; the volatile alkali, which is contained in a latent state in these bodies, is developed; and, lastly, the whole body is changed into earth.

In most of the above-mentioned bodies, these three stages naturally follow each other. But by unskilful management, and too great precipitation, one or the other of these degrees may be passed by, and instead of the spirituous evolution, the acid, or even the putrid fermentation, immediately takes place.

All bodies, however, are not adapted for producing these three degrees of fermentation. For some bodies, which have no ardent spirit in their composi-

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tion, are not capable of undergoing the ſpirituous fermentation, but as ſoon as the inteſtine motion and evolution are occaſioned, paſs directly on to the acid fermentation, and thence, if this be not reſtrained, to putrefaction.

There are alſo ſome other bodies which are neither ſuſceptible of the ſpiritous nor the acid fermentation; but on being thrown into an inteſtine motion, go directly over to putrefaction. Such are thoſe, which have neither an ardent ſpirit nor an acid, but, on the contrary, a redundancy of mucilage in their compoſition, as for inſtance, moſt of the parts of animals.

On the contrary, to the laſt ſtage of fermentation, viz: putrefaction, all organized bodies, without diſcrimination, are ſubject.

All bodies which are endowed by Nature with a ſufficient quantity of phlogiſton and air, need only to be put into a fluid ſtate, and to have a gentle degree of heat imparted to them, in order to be made to ferment. But when theſe conſtituent parts abovementioned are reſtrained in their activity by a redundancy of viſcid matter, certain additaments muſt be uſed for the promotion of this proceſs.

Additaments of this kind, are called *Ferments*. Their whole effect conſiſts in the ſubſtance deſigned for fermentation, the ſolution or ſeparation intended, and which is adapted to its nature. Hence it follows that a ferment muſt poſſeſs certain active and mobile particles. But farther, theſe ferments ought either to conſiſt of ſuch a compound, as is already in this inteſtine motion, and in the very ſtate which is intended to be produced in the bodies ſubjected to this operation: or elſe they may be of ſuch a quality, as to be by their nature capable of beginning only the expected motion and ſeparation. Under the firſt diviſion, are comprized *yeaſt* and *leaven*: to the latter, *an addition of acid and of alkaline ſalt alternately*: likewiſe ſpirits of wine, and even wine-vinegar, applied in various ways.

Every ferment conſequently determines the whole maſs of the fermentable body to which it is added, to the nature of the ferment itſelf, inſomuch, that in the fermentation effected by it, a great quantity of the very ſame ferment is produced afreſh. Thus a body will paſs on to ſuch and ſuch a fermentation, accordingly as this or that ferment has been added to it. This effect depends on the determinate power of a ferment to communicate to the whole fermenting body, a nature ſimilar to its own, by means of an *aſſimilation*, or, as it is otherwiſe called, *appropriation*.

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The aperient or developing fermentation is ſometimes had recourſe to. This is effected by adding bodies that are not eaſily fermented by themſelves, to other ſubſtances that are in a ſtate of fermentation, by which means the evolution of their compoſition is promoted. This is called *Confermentation*, and is uſually practiſed with reſpect to aromatic vegetables; in conſequence of which, their volatile parts are united more intimately with the ardent ſpirit of the fermenting bodies, than when this ſpirit has been barely drawn off from them by diſtillation.

The contrary of every thing that promotes fermentation in a body, will prevent it. And as there are caſes in which it is neceſſary for the fermentation to be checked or ſuppreſſed, it may not perhaps be amiſs to make mention of them in this place. We ſhall, therefore, briefly obſerve, that as fluidity, heat, and the free acceſs of air, promote fermentation; ſo the privation of fluidity, cold, and excluſion of the air, will check it.

The proceſs likewiſe which takes place in the interior part of the grain in germination, has been by ſome conſidered as a real fermentation. But there exiſts a *certain reſemblance* only between theſe two proceſſes, and they are ſo far from being the ſame, that there is rather an eſſential difference to be obſerved between them.

The whole reſemblance of the two caſes, conſiſts in this: 1. That as well in germination as alſo in real fermentation, by virtue of an internal expanſive power, an *inteſtine motion* and *evolution* occur: 2. That as well in germination as in fermentation, theſe take place in the ſoluble and liquefied parts.

But the *difference* appears very evident from what follows. The grain, or rather the germ of the grain, is a body of a peculiar formation, and compounded of many heterogeneous organized parts. Now although it be true, that immediately on its germination, an inteſtine motion and evolution are to be perceived in it, yet it muſt be allowed, that the *phenomena* and *effects* of fermentation are very different. For in *germination*, we obſerve organic evolution—developed veſſels—the conſervation of theſe veſſels—the increaſe and growth of the ſame—conſequently, a progreſſive, expanſive and ſynthetical mechaniſm.—In fine, the *conſervation of the whole ſubject*. On the contrary, in *fermentation* we find—the deſtruction of organized parts—the eſcape of volatile elementary particles—the mutual ſeparation of the chemical conſtituent parts—a retrograde evolution—and, finally, the *deſtruction of the whole ſubject*.

But if in contemplation of effects, we pay no attention to the reſult and final intention of them, the ebullition, or efferveſcence of an acid with an alkaline ſalt,

or with an abſorbent earth, will appear to bear as great a reſemblance to fermentation, as germination does; nay, to the ſenſes, the reſemblance is even more ſtriking: and yet our forefathers have long ſince been very juſtly cenſured for referring, upon the ſtrength of ſome appearances of ſimilarity, effects of this kind to fermentation. The germination of grain therefore, on account of the phenomena abovementioned, and in default of the reſults by which fermentation is characterized, cannot with any foundation be conſidered as a ſpecies of this operation.

For the ſeparation of ſubſtances from their menſtrua, it is neceſſary to have recourſe to different methods, according to the different nature of either.

This may be performed, in the firſt place, when the fluid parts of the menſtruum are of ſuch a nature that they may be ſeparated from the ſolid bodies by mere evaporation. In this operation, an inſpiſſation enſues of the ſubſtance which was before diſſolved: but in the ſecond place, when the union between the two ſubſtances is too intimate to be diſſolved by the former method, the ſeparation muſt be effected by the intervention of another body which is able to deſtroy this combining power.

In the former caſe, the operation is termed *Inſpiſſation*, or *exſiccation*. But in the latter caſe, where the diſſolved body, without any previous evaporation of the menſtruum, is ſeparated in a divided ſtate, and a perfectly indeterminate form, the operation is called *Precipitation.*

Now ſince bodies may, as we have obſerved before, be made fluid in two different ways, viz: either by mere fire, or by the different kinds of fluid menſtrua; the precipitation conſequently ought, in conſideration of this difference, to be diſtinguiſhed into precipitation in the *dry*, and that in the *humid* way. To the former method belongs the precipitation of metallic bodies in fuſion, as it takes place in the ſmelting of ores, or in the preparation of the regulus of antimony, in which caſes, the precipitated metal is called a *regulus:* whereas, on the contrary, a body which is precipitated in the humid way, that is, ſeparated from the fluid menſtruum, by which it was held in ſolution, bears the name of a *Precipitate*, or *Magiſtery.*

This operation, therefore, always pre-ſuppoſes a previous ſolution of the ſubſtance, with which the ſeparation is about to be attempted. Now as in the definition of ſolution we aſſerted, that it conſiſted of a particular combining power of the ſmalleſt parts of the menſtruum with reſpect to the ſmalleſt parts of the ſolvend; the preſent operation of precipitation, of which we are treating at preſent, is founded upon

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the knowledge how this combining power is to be deſtroyed, and the diſſolved body ſeparated again from its menſtruum.

In general, the precipitation of a diſſolved body may proceed from two different cauſes. Firſt, when a third body being added, which is called the *Precipitant*, has a greater affinity with the menſtruum than the diſſolved body has, the conſequence is, that the combining power of the menſtruum with the body firſt diſſolved is diminiſhed and totally deſtroyed; the diſſolved body therefore is by this means forced to ſeparate from the menſtruum, with which, on the other hand, the added body unites. Secondly, when the added body has a greater affinity with the diſſolved body than the menſtruum has; the diſſolved body is compelled to quit the menſtruum, and to unite, on the other hand, with the added third body, and thus to fall from the former ſolution.

From this explanation it is eaſily underſtood, that precipitation borders very cloſely upon ſolution, and proceeds from the ſame cauſe. For precipitation is nothing elſe than a new union, or a ſolution, either of the menſtruum or of the diſſolved ſubſtance with another body; for when the precipitant combines either with the menſtruum or with the diſſolved body, in both caſes, a new union, or a new ſolution of the body, takes place.

The fundamental rules which muſt neceſſarily be obſerved with reſpect to this operation, are the following:

1. Every ſolution from which a precipitation is to be made, muſt be firſt of all perfectly ſaturated with the diſſolved body.

2. It ought to be freed from all undiſſolved particles, or extraneous impurities which may happen to be contained in it.

3. All ſolutions, before the precipitation is attempted, ſhould be diluted with a conſiderable quantity of pure water. (For accurate inveſtigations, diſtilled water is requiſite.) This cauſes a more ſubtile and finer precipitate than is obtained when this precaution is neglected.

4. Bodies which are diſſolved by acids, are commonly precipitated by alkaline ſalts; and thoſe which have been diſſolved by alkalies, by acids. It ſhould be obſerved however, that this rule admits of exceptions; for there occur inſtances, in which acid ſolutions are preciptated by acids, and alkaline ſolutions by alkalies.

5. The precipitant as well as the ſolution ſhould be pure and free from all heterogeneous particles, and alſo, (like the ſolution) be previouſly diluted.

6. The mixture of the precipitant with the ſolution ought not to be made all at once, and in a great quantity, but gradually, and by little and little, becauſe a violent effervеſcence frequently enſues after it; on which occaſion, it is impoſſible to prevent the liquid from running over the top of the veſſel, and, conſequently, from being loſt.

7. During the mixture of the precipitant with the ſolution, the liquor ſhould be kept continually ſtirred, till the effervеſcence, which generally enſues on this occaſion, is obſerved to ceaſe.

8. When the appearances which take place upon the addition of the precipitant, are ſeen to ſubſide, the mixture muſt be ſuffered to reſt for a certain time, that the ſeparated body may ſettle at the bottom. After this, a little of the clear liquor muſt be decanted off, in order to try whether any thing more can be precipitated from it; and if it can, ſome more of the precipitant is continually added, till no farther ſeparation from the clear liquor is to be obſerved. This is the uſual ſign of the precipitation being finiſhed. There are caſes, however, in which it is proper to carry on the proceſs ſtill farther, on which account it is neceſſary farther to obſerve:

9. That all precipitations are not to be conſidered as being finiſhed, on the appearance of the abovementioned, and therefore it will be neceſſary to make trial of ſmall portions of the clear liquor that remains by other precipitants; as alſo to have recourſe to ſeveral other expedients. There are caſes, for example, in which the clear liquor ceaſes to be rendered turbid in the cold by the precipitant made uſe of, but when both the clear liquor and the precipitant are mixed hot together, a great deal more is ſtill precipitated. Sometimes, alſo, the precipitant is prevented by the dilution of the mixture; for which reaſon, evaporation muſt be called to our aſſiſtance.

10. After the operation is ended, the mixture muſt be left to ſtand quietly, in order that the diſſolved body may gradually ſubſide to the bottom.

11. The ſuperincumbent liquor is next to be gently decanted from the precipitate, and different trials are to be inſtituted with it ſuitable to its different nature, in order to diſcover whether it is ſtill capable of being converted to any other uſe.

10. The precipitate is then to be repeatedly covered afreſh with water, till it is freed from all ſaline particles, for which purpoſe, boiling water is ſometimes requiſite: and finally, it is to be dried with a gentle heat.

 When

When the diſſolved bodies, in ſeparating from the menſtruum, aſſume a regular angular form, theſe bodies thus ſeparated are called *Cryſtals*, and the operation itſelf obtains the name of *Cryſtallization*. This operation may be made as well in the humid as in the dry way.

With reſpect to ſalts or ſaline compounds, it is chiefly effected in the humid way, in which caſe it is to be referred to the ſame cauſe with precipitation; and commonly to accompliſh it, nothing more is neceſſary than merely the evaporation of the menſtruum. The determinate figure which theſe bodies are wont to aſſume, proceeds from the original elementary form of their parts, and their attractive power which is in proportion to it.

In order to ſucceed in cryſtallization: 1. The utmoſt attention muſt be paid to cleanlineſs, ſo far as the nature of the circumſtance will permit: 2. The ſolution intended for cryſtallization muſt be ſuperſaturated with the diſſolved body, or elſe be deprived of part of the menſtruum, by an evaporation adequate to the purpoſe, and by this means brought to the proper point of cryſtallization; which point is indicated by a ſaline pellicle covering the ſurface. Upon which: 3. The evaporated ſolution is to be removed to a cool place and left there for ſeveral days: and, 4. The ſame proceſs is to be repeated with the remaining liquor.

The following particulars are to be obſerved with a view to the production of cryſtals larger than common: 1. The greater the quantity is of the diſſolved body, the larger will be the cryſtals. 2. The ley ſhould be ſuffered to ſtand at reſt for a long time, and in a moderately warm place. 3. More ſingle cryſtals are obtained, when ſome clean wooden ſticks, or threads bleached white, are fixed in the middle of the ley.

Sometimes it is more ſuitable with the views of the operator to have ſmall and ſlender cryſtals. Theſe are obtained by removing the lixivia after they have been evaporated to the point of cryſtallization, to a cool place, and,ſtirring them with rods.

In every caſe, there remains after the firſt cryſtallization, a portion of ſaline lixivium, in which the quantity of cryſtals that will be farther formed, is very trifling; the redundant water here preventing any farther cryſtallization. For this reaſon, the water ſhould be ſeparated from it by evaporation, or elſe this weak lixivium muſt be impregnated while it is upon the fire, with a freſh portion of the ſalt to be cryſtallized. But if a ſalt of quite another nature is found to be contained in it, this ought to be left ſeparate. The laſt reſiduum, from which abſolutely no more cryſtals are to be obtained, is by ſome, though very improperly, called the *Mother-water*, or *Mother-ley*.

The cauſe of cryſtallization originates merely in the property of boiling water to diſſolve a greater quantity of ſalt than can be diſſolved by cold water. Now of this property, the artiſt takes the advantage, in order to purify ſalts and to reduce them again to their priſtine form of cryſtals. Thus if his ſalt be impure, he diſſolves as much of it in boiling water as can be taken up by this fluid, and filters the ſolution immediately while it is boiling hot. Here the pure ſalt will paſs alone through the filter, while all the impurities remain behind. Now when this lixivium is ſet by to cool, and ſuffered to ſtand undiſturbed, the quantity of ſalt which the boiling water has diſſolved more than it would have been able to do when cold, will ſeparate as ſoon as the lixivium is become quite cold, at the ſame time forming ſuch regular cryſtals as are peculiar to that particular kind of ſalt with which the experiment has been made. The cold lixivium which remains after this operation, will ſtill contain as much of the ſalt diſſolved in it, as the quantity of water of which it conſiſts, can diſſolve of it when cold. In order to ſeparate this quantity of ſalt entirely, it is neceſſary to evaporate a portion of the liquor, till the ſame proportion takes place again between the water and the ſalt, as there did previous to the firſt cryſtallization. In fact, the liquor muſt be evaporated till the remaining ſalt has juſt as much water left, as is requiſite to keep it diſſolved in boiling water. This point is diſcovered when the lixivium begins to be covered with a pellicle, which is a ſign that there is no longer fluid ſufficient to hold all the ſalt that was contained in it, and that now, the water is not only ſaturated, but ſuperſaturated with the ſalt. When therefore this liquor is ſet by a ſecond time to cool, a freſh quantity of ſalt will again be ſeparated from it, and fall to the bottom of the veſſel; and this is repeated till all the ſalt is cryſtallized.

As every cryſtallization ſuppoſes a preceding ſolution; and as ſolid bodies may be alſo diſſolved in the dry way by fire alone, it follows that a *Cryſtallization via ſiccâ* muſt likewiſe be poſſible. Of this we have an inſtance in metals, as one of the conſequences of *Fuſion*. All ſemi-metals in a ſtate of fuſion, after the fire which is the menſtruum by which the fuſion is effected, has quitted them, form manifeſt and recognizable regular cryſtals. They may be diſtinguiſhed by the naked eye in zinc, biſmuth and antimony, the plaineſt of any: but they have alſo been diſcovered in melted gold, ſilver, iron, copper, lead and tin. In like manner may the ſublimates of different ſalts which form peculiar and diſtinct cryſtals, as ſal ammoniac, for inſtance, ſedative ſalt, and ſuch ſaline metallic ſubſtances as are

are obtained by *Sublimation*, be referred to this head; ſince all theſe, after having undergone a previous ſolution by fire, have been reduced into the abovementioned regular form.

*Reduction*, finally, is an operation which takes place with reſpect to metals only, and by which, when by any means whatever they have loſt their metallic appearance, they are perfectly reſtored to their former ſtate.

As metals may be deprived of their metallic appearance in two different ways, either by the privation of their phlogiſton, as is the caſe in calcination; or elſe by uniting with them various kinds of extraneous, and thoſe chiefly ſaline or ſulphureous ſubſtances. The reduction conſequently depends on a two-fold cauſe, and requires either that the metallic earths ſhould have that which they have loſt reſtored to them, or that the extraneous ſubſtances which have been united with theſe calces, ſhould be ſeparated from them.

But previouſly to undertaking the reduction of one of theſe ſubſtances, the nature of the metal which is to be reduced, and the means by which it has loſt its metallic properties, ſhould be taken into conſideration: when it will generally be found that the phlogiſton of baſe metals and ſemi-metals is diſſipated, and that moreover they are ſometimes united with ſome extraneous acido-ſaline or ſulphureous body.

There is at all times a great difference obſervable in Reductions. Some are performed with eaſe; ſome, on the contrary, with greater difficulty, and require beſides to be managed in various ways. Some may be reduced in open crucibles, whilſt others are only to be reduced in cloſe veſſels. In ſome caſes the whole of the metal which is contained in the body to be reduced, is obtained: in others, on the contrary, a conſiderable quantity of it is loſt.

The parts which the metallic calces have loſt, are reſtored to them by fuſing the calces in fire together with ſome other body which contains theſe parts. But the extraneous ſaline or ſulphureous particles are in like manner withdrawn from them by ſuch ſubſtances as by their nature are adapted to this end. The latter kind of materials, however, are ſeldom uſed alone; becauſe generally in ſuch caſes, the inflammable portion has been parted with at the ſame time: both theſe kinds of reducing ſubſtances therefore ought to be made uſe of together.

As we know from chemical analyſis that in all the different parts of vegetables and animals there exiſts a ſufficient quantity of phlogiſton, and that this

* And (according to the new theory) by addition of air. [E]

 ſubſtance

ſubſtance is one and the ſame throughout all Nature, and conſequently in the three kingdoms; it is at our option to extract it from any body whatever, as it ſuits us beſt. Accordingly, all bodies which contain it in abundance, *ſulphur** only excepted, will be found perfectly well adapted to this purpoſe. The fitteſt, are *tallow*, *pitch*, *colophony*, *wax*, *wood-ſoot*, *charcoal*, *olive-oil*, *greaſe*, *train-oil*, *ſoap* and *tartar*.

The other kind of reducing ſubſtances, by which metallic calces may be deprived of the ſulphur or ſalts that adhere to them, are *calcareous earths*, *chalk*, *clay*, *fixed alkali* and *borax*. In many caſes alſo, different metals may be uſed.

Of the operation itſelf, the chief circumſtance to be obſerved is, that all bodies which are to be reduced, muſt be fuſed together with the reducing ſubſtances. For by this means only are their ſmalleſt particles put in motion, as alſo in a condition to unite with the conſtituent parts which are wanted, of the ſubſtances added. Hence the calces of metals are commonly the ſooner reduced, the more fuſible they are; and therefore when they are not naturally inclined to fuſion, they muſt be aſſiſted with ſaline ſubſtances, which promote the fuſion of them in fire. At the ſame time care ſhould to be taken that no ſalt be uſed, which upon other accounts is contrary to the end propoſed, and ſometimes might even prevent the reduction. Thus alkali may be pernicious in many caſes in which ſulphur enters into the compoſition of a metallic body.

Farther, the more perfectly metallic ſubſtances have been calcined, the more difficult the reduction will be of them. It ſucceeds beſt, when there ſtill ſubſiſt in the body, that is to be reduced, ſome inflammable particles; without which, the phlogiſton of the reducing ſubſtances cannot ſo eaſily combine with the calcined earthy particles, and conſequently reduce the metal.

It is alſo remarkable with reſpect to this operation, that it is almoſt always attended with a conſiderable loſs of the reduced ſubſtance. No metal, except gold and ſilver, can be deprived of its metallic appearance, and afterwards regain it by this operation, without ſuffering a loſs of weight, which is greater or leſs, according to the difference of the circumſtances. The cauſe is probably to be ſought for either in the great violence which the metal muſt neceſſarily ſuffer during its deſtruction, or in the violent action of the fire, which the metallic calx muſt unavoidably ſuſtain during its reduction; or elſe there remain behind in the flux ſome ſmall molecules, which it is almoſt impoſſible to ſeparate from it entirely.

* Phoſphorus likewiſe, at leaſt in the dry way, is an exception to this rule. [E]

When

When phlogiston is the chief requisite in reduction, every substance is improper that does not burn in the fire, or else detonate with nitre. It ought farther to be observed, that crude tartar is sometimes fitter to be used than charcoal; because it contains much more alkaline salt; and, on that account, promotes the fusion. Finally, it is necessary also, that for the sake of promoting the fusion and increasing the heat in the metal to be fused, care should be taken that the metal be covered with the flux, and that the flux be of such a nature as not only to receive the most intense heat, but at the same time also promote the vitrification of extraneous matters. This is frequently effected by a copious addition of common glass to the black flux.

To this same operation may be likewise referred the *revivification* of mercury. This is indeed merely a species of reduction, and bears a reference merely to the various preparations of mercury. Since mercury is a body volatile in an ordinary degree of fire, it is easy to conceive that the reduction of it cannot be effected in an open crucible, but must be performed in close vessels.

As mercury may be deprived of its metallic properties, either solely by the matter of fire*, or by sulphur, or acids, or by other metals, the reducing substances must be selected according to these different cases; a subject which we shall treat of more particularly in its proper place.

## SECT. II. A Synoptical View of the Operations of Chemistry.

Every chemical operation consists either in the separation or conjunction of two or more heterogeneous bodies, or parts of bodies.

But the separation of two or more heterogeneous bodies, or parts of bodies, is effected either by their *volatilization*, or *liquefaction*, or *concretion*.

By volatilization is effected: 1. The separation of fluids from fluids, called *Evaporation*, when the volatilized part is neglected; and *Distillation*, when it is saved.——2. Of solids from solids, called *Ustulation*, or *Roasting*, when the volatilized part is neglected; and *Sublimation*, when it is saved.——Of fluids

* Or rather, (according to a more enlightened theory) by receiving air, and at the same time parting with its phlogiston.

from

from ſolids with abſorption of air by the ſolid part, the volatilized part being neglected, which operation is termed *Calcination*.

Liquefaction is effected either by heat, (*Fuſion**), or by menſtrua, (*Solution*).

When a ſubſtance is ſeparated from a fluid holding it in ſolution, by concretion in that fluid, it is either by the ſubſtraction of heat from the mixture, (*Cryſtallization* Sp. 1. *Concentration*, Sp. 2. viz: by freezing)——or of part of the menſtruum (*Cryſtallization*, Sp. 2. *Precipitation*, Sp. 3.)——or by the addition of heat uniting with, and rendered inactive by the diſſolved body (*Coagulation*, Sp. 1.)——or by the addition of a third ſubſtance combining either with the menſtruum (*Precipitation*, Sp. 1. *Cryſtallization*, Sp. 3.)——or with the diſſolved body (*Precipitation*, Sp. 2. *Coagulation*, Sp. 2.)

* Fuſion and evaporation, which are the immediate effects of heat on bodies; condenſation and freezing, which are the immediate effects of cold, or of the abſence of heat, when they affect the homogeneous parts of bodies only, are by no means to be conſidered as chemical operations; becauſe heat has no effect whatever in tranſpoſing the heterogeneous particles of bodies, excepting when theſe particles have different degrees of volatility, i. e. different degrees of attraction for that Element. Thus neither the fuſion of lead alone, the melting of wax, nor the evaporation nor even diſtillation of pure water, can be properly called chemical proceſſes: but the extraction of lead from its pure ore by fuſion, and ſtill more ſo the evaporation and diſtillation of a mixture of ardent ſpirit and water, may be legitimately aſcribed to chemical powers. The ſame may be ſaid of the concentration of brine, or of vinegar by freezing. However, it muſt be owned, that the abovementioned operations, are only *accidentally* chemical. But the fuſion of two ſubſtances together which act upon each other, is a kind of *dry Solution*, and truly chemical. It is this ſpecies of fuſion which is referred to under the head of *Conjunction*, in the following Table. The other ſpecies, or fuſion *per ſe*, is very improperly referred to ſolution.

# TABLE OF CHEMICAL OPERATIONS.

## *CONJUNCTION.*

**1. Solution.**
- a. Proper.
- b. Diffuſion.
- c. Deliqueſcence.
- d. Amalgamation.
- e. Infuſion.
- f. Decoction.
- g. Fermentation †.

**2. Fusion.**
- viz. *With addition.*

**3. Reduction.**
- a. Proper.
- b. Revivification.

**4. Impregnation*.**
- a. Proper.
- b. Cementation.

**5. Corrosion††.**

## *SEPARATION,*

### A. *By VOLATILIZATION.*

**1. Evaporation.**
- a. Concentration, Sp. 1.
- b. Inſpiſſation.

**2. Distillation.**
- a. Cohobation.
- b. Abſtraction.
- c. Dephlegmation.
- d. Rectification.

**3. Sublimation.**
- a. Proper.
- b. Uſtulation.

**4. Calcination.**
- 1. *By Heat.*
  - a. Incineration.
  - b. Reverberation.
  - c. Detonation.
  - d. Decrepitation.
  - e. Calcination proper, Sp. 1.
  - f. Vitrification.
    - 1. Scorification.
    - 2. Cupellation.
- 2. *By Water*
  - g. Calcination, Sp. 2.

### B. *By LIQUEFACTION.*

**Extraction.**
- 1. *By ſimple Fuſion*‡. Eliquation.
- 2. *Solution in Water.* Edulcoration. Elixation ***.
- 3. ——— in *Quickſilver*, or by *Amalgamation.*
- 4. ——— in *other Menſtrua* **.

*Parting.*
- a. *Simple*, or Quartation.
- b. ——— Dry.
- c. ——— Concentrated.

### C. *By CONCRETION,*

*With the Menſtruum.*
- a. Precipitation, Sp. 1.
- b. Cryſtallization, Sp. 3.

*With the diſſolved Subſtance.*
- c. Precipitation, Sp. 2.
- d. Coagulation, Sp. 2.

*By Subſtraction of the Menſtruum.*
- e. Cryſtallization, Sp. 2.
- f. Precipitation, Sp. 3.

*By Cold.*
- g. Cryſtallization, Sp. 1.
- h. Concentration, Sp. 2.

*By Heat.*
- i. Coagulation, Sp. 1.
  - 1. Clarification.
  - 2. Deſpumation.

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* Viz. Of leſs with more fluid bodies, e. g. of water with aerial acid, nitrous or alkaline gas. † Fermentation is a continued ſolution, and therefore is properly arranged under this head. But, it may be ſaid, it likewiſe acts by ſeparation. Yet as, at leaſt in the vinous and acetous fermentations, the matter thus ſeparated from the general maſs, are all excrementitious: and Nature appears to have intended for our uſe the products of the *conjunctory* proceſs only, it is beſt to view the whole proceſs in this light. †† Corroſion ſeems to differ from calcination inaſmuch as in the latter air only is added to the metallic calx: whereas in this the calx is united both to air and acid. ‡ Viz. Of metals from metals, of metals from their ores, of fat from the membranes containing it, &c. or the ſeparation of a more fuſible from a leſs fuſible body by heat. ** Viz. The ſeparation of metals from metals by menſtrua. *** Analogous to this is *Elutriation*, or the ſeparation of the lighter parts of ſolids from the heavier by water: but this operation, being merely mechanical, cannot have a place here.

## CHAP. VI. ELECTIVE ATTRACTION.

### SECT I. THE SUPPOSED LAWS OF ELECTIVE ATTRACTION.

NOT only are we ignorant of the *cauſe* of the elective attractions of different bodies; but even the *laws* by which they are governed have by no means as yet been ſufficiently inveſtigated. M. *Wenzel*, indeed, has deduced from his obſervations the following law*:

"The affinity of bodies to a common menſtruum is as the times of the ſolutions."

But this rule, although it has greatly the appearance of being founded in truth, unfortunately cannot be reduced to practice: as there are many caſes in which the time taken up by the ſolution is ſo inconſiderable, that the degrees of affinity between the different ſubſtances cannot be determined by it.

The other law, laid down by *Beccher* and other German writers, and lately reviſed by Mr. *Kirwan*, ſeems to afford a more practical rule to the Chemiſt. It is as follows:

"The quantity of real acid, neceſſary to ſaturate a given weight of each baſis, is inverſely as the affinity of each baſis to ſuch acid,

And the quantity of each baſis, requiſite to ſaturate a given quantity of each acid, is directly as the affinity of ſuch acid to each baſis."

But this rule has not been ſufficiently inveſtigated in the various circumſtances in which it is capable of being applied, to be eſtabliſhed into an abſolute and invariable law. Leaving therefore this ſubject to be elucidated by future experience, we ſhall paſs on to another nearly related to it, but which, though ſtill in ſome meaſure involved in perplexity and confuſion, has more certainty as well as utility attached to it.

* In his "Doctrine of the Affinity of Bodies." Lehre von der Verwandſchaft der Korper. Dreſden, 1777.

## SECT. II. THE ORDER OF SINGLE ELECTIVE ATTRACTIONS.

This order has been of late years inveſtigated with great ſucceſs by Profeſſor *Bergman*, whoſe tables are therefore ſubjoined at the end of this volume.

The upper ſtratum of theſe tables, as publiſhed by their illuſtrious author, contains fifty-nine rectangles placed horizontally, and exhibiting fifty-nine different ſubſtances. Theſe ſubſtances are, as it were, the heads of each column, at the of top which they reſpectively ſtand. To theſe, the nearer thoſe ſtand which are placed below, the ſtronger attractions they muſt be underſtood to have. Every column therefore muſt of courſe not only exhibit every one of the fifty-nine ſubſtances which is capable of being combined with the principal ſubſtance at the top, but alſo the order which ſuch combinations follow. Theſe tables moreover are divided horizontally into two parts by a double line: the upper part ſhewing the attractions that take place in the *humid* way; and the lower, thoſe which occur in the *dry* way: both partitions equally referring to the ſubſtances at the top of each column.

But as ſeveral of the ſubſtances placed at the head of each column exhibit the ſame attractions; for the ſake of bringing theſe tables into a ſmaller compaſs, and conſequently of adding to their perſpicuity, as well as rendering them in other reſpects more convenient, we have, in imitation of Dr. *Berkenhout**, placed thoſe ſubſtances together which have the ſame attractions, at the head of the ſame column, and as well by this means as by omitting ſeveral other ſubſtances, reduced the number of columns in the partition exhibiting the attractions in the *humid* way, from fifty-nine to thirty-ſix, and in the other, to a much ſmaller number, viz: twenty-five.

The number of columns thus differing in each partition, the exhibition of both of theſe together in one page could anſwer no other purpoſe than that of increaſing the bulk of the table, and conſequently of rendering it more cumberſome and inconvenient to the reader. We have therefore parted them entirely, and made two ſeparate tables, one for the attractions operating in the *humid*, and the other for thoſe that act in the *dry* way.

By way of farther condenſing the tables, we have with Dr. *Berkenhout* omitted the three columns of the phlogiſticated and dephlogiſticated acids, as well as that of aqua regia, they being merely repetitions of the firſt column. That containing

* In his "Firſt lines of Chemiſtry."

the

the acid of wood-ſorrel is likewiſe omitted, as it is diſcovered that this ſubſtance and the acid of ſugar, which is therefore called the *oxaline acid*, are the ſame. The perlate acid too, as well as the pretended new metal, called *ſiderite*, being now known for compounds containing the phoſphoric acid, are rejected from this table.

The acid of fluor is placed at the top of the ſame column as the tartaric and oxaline acids, from which it does not differ in point of attraction, excepting that it has an affinity with ſiliceous earth, which the other two do not exert. This excluſive affinity accordingly is expreſſed at the bottom of the column in the ſame manner, as the affinity of the ſame earth with the boracic acid in the dry way is indicated in the ſecond column of the ſecond table.

In *Bergman's* tables, the two fixed alkalies exhibit the ſame attractive powers; and the column of *volatile alkali* differs from thoſe of the *fixed alkalies* in one particular only, viz. that at the bottom of the former, *metallic calces* are placed, and of the latter, *phlogiſton*. But as the learned Profeſſor publiſhed his tables long before the complete diſcovery of the compoſition of the volatile alkali by M. *Berthollet*, and as he has not adduced any experiment in ſupport of this variation, we have taken upon us to reduce the three columns to one. A ſimilar apology muſt be made for the liberty we have taken with the column of *arſenic*, in which, probably induced by Mr. *Sage's* well-known experiment of the reduction of arſenical acid by phoſphorus, and M. *Pelletier's* reduction of the ſame acid by inflammable gas, he had ranked phlogiſton above water and alcohol. But there appears to be no good reaſon for departing in this inſtance from the general order of the attraction of the acids: as both theſe phenomena are certainly the reſults of a double elective attraction.

As the vegetable alkali conſtantly precedes the mineral in the order of attraction, we thought it it needleſs to make two ſeparate columns for them; rather chuſing to leave it to the reader to impreſs this fact on his memory.

The reader is likewiſe requeſted to obſerve the following general rules with reſpect to elective attractions, as indicated by Dr. *Berkenhout*, (l. c.)

1. All acids, excepting Pruſſian blue, prefer earths to alkalies.

2. All acids prefer the other earths and alkalies to alumite, or earth of alum; and the fixed to the volatile alkali; and earths and alkalies to metallic calces.

Thus much for the firſt table, containing the attractions in the *humid* way. As for the other table exhibiting thoſe in the *dry* way, we have only this obſervation to make, viz: excepting in the caſe of the three acids which occupy the

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three firſt rectangles in the column of alkalies, with which, on account of its volatility, the alkali of ſal ammoniac will not unite by fire, all the alkaline ſalts poſſeſs the ſame attractive power. This is ſufficiently indicated in its place, at the top of the column.

In both the tables, the reader will pleaſe to obſerve, that wherever an aſteriſc occurs, the ſubſtance immediately preceding it in the ſame horizontal row, muſt be underſtood to be repeated: and alſo that in order to make each column occupy as narrow a ſpace as poſſible, acids are denoted by a croſs, thus ( + ), and metallic calces by this mark ( ♀. )

Beſides the arrangements here indicated, and the rejection of the columns exhibiting the attractions of pure air, and of the matter of heat, which are evidently defective, we have attempted no other eſſential alteration in theſe tables; although, according to our theory, of which their illuſtrious author had no conception, the union of by far the greater part of the ſubſtances here indicated, takes place in conſequence of a double, inſtead of a ſingle elective attraction. In fact, to make alterations to any purpoſe, the tables muſt be entirely conſtructed afreſh, and who ſhall undertake the taſk after *Bergman?* If however this buſineſs ever is undertaken, and executed with ſucceſs; we ſhall probably owe ſo uſeful a work to the united labours and ingenuity of thoſe egregious Philoſophers Meſſrs. *Lavoiſier* and *Berthollet**, if at any time, totally diveſted of prejudice, and open to conviction, they ſhall be diſpoſed to admit the doctrine of phlogiſton, without cavil or limitation.

From what we have juſt ſaid, it will be eaſily conceived, why we have declined augmenting theſe tables with the attractions of the Barylithic, Melic, Bombycic, Gummic, Camphoric, Molydænic, Lignic and Zoolithic acids, thoſe of the acid of Cork, or of the newly diſcovered element, Mephitis.

So much for the ſingle elective attractions: as for the double attractions, they are ſo numerous that ſeveral ſheets would not have ſufficed for the repreſentation of their different ſchemes: we therefore thought it better to omit them altogether, and content ourſelves with mentioning ſome of the principal of theſe attractions, as they occur in the courſe of this work.

* We are not entirely without hopes of ſeeing this period ſoon arrive; as the ſtrongeſt plea which M. *Lavoiſier* had to urge againſt the doctrine of phlogiſton; viz, *Entia non debent multiplicari abſque neceſſitate,* is now annihilated by his admiſſion of the exiſtence of this ſubtle matter, or of what is equivalent to it, light, in many ſubſtances, and particularly in the air.

## CHAP. VII. GENERAL RULES, TO BE OBSERVED IN CHEMICAL INQUIRIES.

### SECT. I.

IT may not be amiſs to conclude this ſyſtem of pure and unmixed Chemiſtry with ſome general fundamental rules, neceſſary to be obſerved in every chemical inveſtigation of natural bodies that is expected to be attended with ſucceſs, and to anſwer the purpoſes of its inſtitution. With this view, I have incorporated with ſome others, the very ſenſible maxims publiſhed by Dr. *Struve* *, relative to the ſame ſubject, and with the ſame intention.

In the firſt place, every one that intends to apply himſelf to the inveſtigation of natural bodies, or indeed to any other department of practical Chemiſtry, muſt neceſſarily be acquainted with the principles of the art; he ought likewiſe previouſly to have enlarged the ſphere of his knowledge by the diligent peruſal of ſuch chemical writers as deſcribe the operations and experiments made by practical Chemiſts, and in which the methods to be taken for this purpoſe are beſt laid down. More eſpecially he ſhould endeavour to make himſelf as well acquainted as poſſible with every thing that is to be found in authors, relative to the ſubſtances he intends to operate upon, or to inveſtigate; in order that he may be able, on the one hand, to make uſe of them in his experiments; and, on the other, to compare his own obſervations with theirs, and thereby diſcover what they have left for his inveſtigation and inquiry.

Now as the moſt ordinary mechanic always turns over in his mind the buſineſs he has undertaken, before he goes to work upon it, much more is it requiſite for the Chemiſt, previous to all his intended operations, to lay down a plan according to which they are to be conducted, as well at the commencement, as throughout the whole. His next care muſt be to have every article neceſſary, as well with reſpect to materials as inſtruments and veſſels ready prepared and

* In the *Bern* Magazine of Nature, Art and Science, Vol. I. part 2. page 55,—66.

at hand, in ſuch order and condition, as to be fit for immeditate uſe. He muſt then repreſent to himſelf, in idea, the execution of his plan in each particular period of it, and with all its imaginable reſults and conſequences, and revolve in his mind, ſingly, every circumſtance that may probably occur in the operation, as well in order to avoid meeting with untoward accidents, as for the ſake of paying due attention to the various phenomena and appearances of the proceſs. But at the ſame time he muſt cautiouſly avoid conſidering theſe reſults as fixed and abſolutely certain, or to diſtort and mould them according to the dictates of his own imagination, as this would be a moſt dangerous digreſſion from the ſubject, and might accuſtom him by degrees to place too great a dependance on pre-conceived opinions, a practice from which every Chemiſt, that is a friend to truth, ſhould be careful to keep free and unbiaſſed. In operations therefore, with which he is as yet unacquainted, the reſult muſt be determined in the way of *conjecture* only; and one ought to ſuſpect one's own deciſions upon the ſubject, to the end, that every change that may take place different from them, may be contemplated with a cool indifference.

After theſe preparations, the artiſt may proceed to the operation itſelf. Here he muſt be particularly careful to conduct every thing very leiſurely and orderly, as well as with the greateſt coolneſs, attention and foreſight. To this muſt farther be added, cleanlineſs with reſpect to the veſſels, and to all the neceſſary materials which are beſt and ſafeſt prepared, by the operator himſelf. From the beginning to the end of the proceſs, the greateſt exactneſs muſt be obſerved: every thing muſt be compounded by weight and meaſure; and again, as far as it is feaſible, the weight of each product ſhould be aſcertained. In the operation itſelf, the greateſt attention is to be paid even to the moſt minute appearances and changes that occur: but at the ſame time, every ſuggeſtion of the imagination, and of a paſſion for the marvellous, muſt be ſuppreſſed; and each concomitant circumſtance is to be obſerved with the greateſt poſſible coolneſs. In ſhort, the operator muſt attend to that which actually does take place, and not to that which, in his idea, ought to take place. The neceſſity for all this, evidently appears in thoſe caſes, in which we are obliged by the appearances and reſults of the operation, to make various alterations in our original plan. For when we are going to treat ſubſtances we are quite unacquainted with, no invariable plan can for the moſt part be laid down; as frequently one ſingle phenomenon will oblige us to adopt a method diametrically oppoſite to that which we at firſt intended to take. Now if the operator, thus circumſtanced, ſhould be pre-occupied in his opinions, and not ſufficiently calm and indifferent, he

will not be able to form a right judgment of ſuch appearances as he did not expect, and will ſcarcely, if at all, attain the ſcope and end of his labours.

Unſhackled therefore by hypotheſes, and diveſted of all pre-occupation and prejudice, his ſole care muſt be to note down all the phenomena, together with the order in which they occurred, and the concomitant circumſtances. To this head may be referred the meaſure, weight, the order of compoſition, the degree of the heat applied, colour, proportion, ſmell, taſte, decreaſe and increaſe of weight and bulk, vapors and their nature, whether they are elaſtic or not, turbidity of the mixture and precipitation, the time employed, the nature of the veſſels and implements made uſe of, and many more, to all appearance, trifling circumſtances of this kind. It may often be very uſeful to have marked down, even the moſt trifling phenomena; in conſequence of neglecting which precaution, we may often be forced to repeat the experiment, and have laviſhed time and expence to no purpoſe.

Patience, in every inveſtigation, cannot be too much recommended; as, where their qualification is not wanting, phenomena frequently occur, which in default of this, and in a precipitate manner of operating, would not have been obſerved. And even if in any one proceſs, ſeveral different products ſhould be obtained, as is very frequently the caſe, each of them ſhould be more narrowly and cloſely examined into, one after the other, in its turn; as otherwiſe the inveſtigation would be but imperfect, ſhould we ſtop at any one of them. In ſhort, all reſearches of this kind muſt be made with accuracy and attention, and in ſuch a manner, that after the operation upon a body is finiſhed, nothing remains farther to be inveſtigated; and there is no room to wiſh that we had done it better.

The great variety of natural bodies exiſting, convinces us immediately on ſeeing them, that they muſt be very different from each other, as well with reſpect to their conſtituent parts, as to the mode of their combination; and hence it very naturally follows, that we cannot attain to a knowledge of them in one general mode; but that they ought to be treated in a very different method. In how many ways do not the bodies of the mineral kingdom differ from the bodies of the two other kingdoms? and farther, how greatly do the bodies in each kingdom differ from another? and how many diſtinct parts beſides occur in the organized bodies of the two latter kingdoms, which muſt all be inveſtigated in a peculiar manner? Now here it is that the greateſt difficulty lies, which muſt, in fact, be overcome, before we can make ſo much progreſs in this ſcience, as to undertake and accompliſh the chemical inveſtigation of natural

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bodies, ſo as to be adequate to every purpoſe. The bodies therefore of each kingdom in general, and then again, each of their different claſſes in particular, muſt be ſubjected to our labours and practical reſearches.

The inveſtigation of any ſubſtance which is the object of our reſearches, muſt be ſimple at firſt, and afterwards carried farther by degrees. Our ſenſes are firſt to be employed; by their aid the ſubſtance is to be conſidered according to its external appearance, and compared with other known bodies, and by this means it is to be determined whether it belongs to the bodies of the mineral, vegetable or animal kingdom, and whether it be an earth, ſtone, metal, ſalt, reſin, or oil. If for this purpoſe the mere external appearance is not ſufficient; the ſmell, the taſte and the touch, are to be called in to our aſſiſtance.

When our ſenſes have diſcovered thus much to us, we muſt then, upon this indication, proceed to inveſtigate the nature of the body before us, whether it be of the mineral, vegetable or animal kingdom. For this purpoſe, it is above all things neceſſary to know all the properties of the pure unmixed bodies hitherto known, and their action upon other bodies, and what is produced by ſuch combination, to the end that from the phenomena that preſent themſelves, we may form an accurate judgment of the combination or ſeparation that has taken place.

The examination of the bodies belonging to the *mineral kingdom* uſually commences with the ſimple natural ſubſtances. And firſt, their affinity to the air muſt be tried, by expoſing them to it for a time, and by obſerving the changes that take place; whether the bodies decreaſe or increaſe in weight, and conſequently whether they loſe or acquire certain parts. Even the moſt trifling change is the effect of ſome cauſe, and ought to be taken notice of. Secondly, their affinity to water is to be inquired into, and whether this latter ſubſtance will not take up ſome parts from them, which may be aſcertained by the colour and taſte. Theſe are then to be determined with greater accuracy and preciſion by making them appear in liquids, by means of other re-agents, or of precipitating ſubſtances, or by evaporation of the water. In the ſame manner *ſpirit of wine*, *ethereal* and *expreſſed oils*, may be employed on ſome bodies of the mineral kingdom. But upon the fixed earthy or ſtony bodies the ſaline ſolvents commonly exert the ſtrongeſt action, namely, the various kinds of acids, either diluted or concentrated, either in a ſimple or in a compound ſtate: what cannot be effected by one acid in this way, will often be brought about by another. By the new properties which ſuch ſolvents acquire, and by the phenomena which accompany them, the nature of the matter that has been extracted and taken up, may

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ſometimes in ſome meaſure be judged of, of which however we may be moſt certainly convinced by the ſeparation that is next to be attempted, by means of different precipitants. But if the ſolution of a body cannot be effected by theſe gentle means, it muſt be attempted by means of fire, which acts more powerfully. For this purpoſe, ſuch bodies muſt firſt be treated in cloſe veſſels, in order to diſcover by this means whether ſome volatile parts do not eſcape from them, and of what nature theſe are; they may then, in the ſecond place, be fuſed together with different ſubſtances with a briſker fire, either by way of effecting a ſeparation, an attempt is thus made to attain in ſome meaſure, or in conſequence of the combination that takes place, to a knowledge of their nature.

The bodies belonging to the *vegetable kingdom* muſt be treated in cloſe diſtilling veſſels, with regard to their *ethereo-oleaginous* particles; but if they contain *unguinous oils,* theſe are obtained by expreſſion. The oleaginous particles that lie deeper and are diſperſed throughout the whole of their compoſition, muſt, on the other hand, be educed by a dry diſtillation, but the *ardent ſpirit* by fermentation only. Their *gummy* parts are to be extracted by water, and obtained by evaporation; for the *reſinous* parts, ſpirit of wine is ſubſtituted to water, and the bodies to be extracted muſt previouſly be gently dried. If they contain a *volatile acid,* this is to be educed partly by dry diſtillation, and partly by fermentation. The *volatile alkali* is moſt completely diſengaged by putrefaction; but the *fixed alkali* with the fixed *neutral ſalts* and *earth* are moſt certainly developed by combuſtion. Their *eſſential ſalts,* which may be conſidered as a neutral compoſition of all the different kinds of ſalt contained in them, are to be obtained from their expreſſed juices, merely by purification and cryſtallization.

In *animal bodies,* the ſureſt way of determining the proportion of the *oily parts, volatile alkali* and *earth,* is by means of dry diſtillation, from which latter ſubſtance the acid is ſtill to be extracted in a particular way, which will be deſcribed in another part of this work.

After the completion of theſe and ſimilar operations, and not till then, the cauſes of all the phenomena and changes are to be ſought for; and it ſhould be obſerved withal, that they often originate in the particular properties of the bodies, and frequently alſo in a combination that has newly taken place. The young Chemiſt muſt likewiſe be careful not to alledge any thing as the cauſe of an effect which cannot be made out to be probable; as nothing is eaſier than to take that for the cauſe of a phenomenon, which in reality is not ſo. Diligent inquiry therefore ſhould be made whether the changes that have taken place may not have been

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produced by a different caufe, and whether poffibly more than one caufe have not operated? likewife whether part of the phenomenon be not more accidental than effential, and confequently do not always take place?

When different hypothefes exift concerning the fame object, all founded upon experiments, it fhould be particularly confidered whether in each of them there is not fome truth, and whether by their combination a true theory may not be compofed.

The drawing of general conclufions from fingle and folitary obfervations fhould alfo be very carefully avoided, as well as the confining of Nature to laws which are not taken from Nature herfelf, and have no foundation but in our own limited imagination. This is a very common error, which cannot be too feverely reprehended. In all conclufions therefore deduced from experiments, the utmoft caution and the ftricteft felf-examination ought to be practifed. Impelled by vanity, and a blameable defire of invention, for which but few have the requifite talents, many imagine themfelves to have obferved appearances, fuch as, befides themfelves, no man divefted of prejudice, is able to perceive.

Every obfervation muft be compared with other fimilar obfervations already known, and not one fingle circumftance only, but all the phenomena that accompany it, fhould be confidered jointly, with the greateft care and attention. Similar effects have ever fimilar caufes; and hence we conftantly endeavour to judge the unknown by the known, and to derive certain rules from experience. Notwithftanding all this, however, *to doubt rationally*, will alway remain the beft general rule. He that doubts of nothing, tries nothing, and he that tries nothing, difcovers nothing. He therefore who wifhes to make difcoveries, muft try, doubt, and not be too eafy of belief. In extraordinary and doubtful cafes, therefore, it is more adviseable to repeat the experiment, in order to be able the better to obferve every circumftance belonging to it: if every thing turns out the fame as before, there is great reafon to believe that the operation has been rightly conducted. For the greater fecurity, it will alfo be proper, by way of difcovering the active principle, to make various counter-experiments under different circumftances, or even to make fuch as are fimilar to the former, or fuch, from which, in another manner, agreeably to the fuppofed caufe, the very fame effect muft enfue.

As well in the combination as in the feparation of bodies, which the artift propofes to himfelf, he muft previoufly recall to his memory the whole aggregate of the affinities and active powers of fuch bodies, and fee which of them is beft adapted to his purpofe. In unorganized bodies, where it is poffible, the jufteft

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analyſis ſhould be confirmed by an artificial ſyntheſis, in like manner as the natural compoſition ſhould be confirmed by analyſis. By this means the natural compoſition of bodies is diſcovered, and the artiſt, in conſequence of this knowledge, learns to imitate them. Let every Chemiſt however mark this incontrovertible rule*: *that, not every thing that is effected by Nature, is poſſible to be produced by art.*

Farther, inaſmuch as the artiſt after having finiſhed the operation, has ſingly and leiſurely conſidered all the reſults and conſequences of it, and explained their cauſes to himſelf, ſo that all the changes that have taken place may now be ſeen with a ſingle glance; it muſt be an eaſy matter for him, as well to draw a uſeful application from it, as to perceive in this or that part of it, either an improvement, or abridgment of the proceſs (ſuppoſing there be room for ſuch); as alſo whether the phenomena exhibited in it might not give riſe to various new diſcoveries.

Laſtly, in committing to paper theſe obſervations and inquiries, whether they are made for our own information and uſe, or for thoſe of the public, the following particular ſhould be attended to.—As in the plan of an operation every thing ſhould be contrived and laid out in conſequence of a due degree of reflection, and agreeable to certain rules and maxims, ſo in writing down the reſults, it is extremely uſeful in every reſpect, at each period of the operation, to mention at the ſame time, one's thoughts, views, and reaſons why this or that has been done ſo and not otherwiſe. It is preciſely by this practice, that the methodical and regular operators are diſtinguiſhed from the mere bunglers, who often work with great aſſiduity, but quite at random, without any knowledge of the body upon which they are operating, and without any rational aim, and conſequently to no manner of uſe or purpoſe. In this way all experiments are rendered inſtructive to every one that reads the deſcription of them. Beginners, by this means, learn to think agreeable to chemical principles; they are rendered capable of diſtinctly perceiving the plan and views of the operator, as well as the different effects and conſequence

* The contrary however to this incontrovertible rule, I have no doubt, is ſtrictly true: viz. that with reſpect to Chemiſtry, whatever is effected by Nature, provided we know the means taken by her, may be performed by art; or, in other words, no analyſis of bodies is genuine, which is not confirmable by ſyntheſis. It is true, this reduces our knowledge of the conſtitution of natural bodies to an extremely ſmall compaſs: for if this be the caſe, what do we know as yet of metals, or of oils, gums, and in general all the educts or products of organized bodies? But the rapid progreſs made by philoſophical Chemiſtry (though ſtill in its infancy) within theſe few years, encourages us to hope that we ſhall not be long in this ſtate of ignorance, with reſpect to the bodies that ſurround us: ſince with the increaſe of Chemical Science, the boundaries of this ſpecies of knowledge muſt neceſſarily be extended. [E]

of the experiments, and the easier attain the point, which frequently the operator has not been able to arrive at himself. By this means, consequently, a road is opened for new experiments, by which new discoveries are made, and fresh truths are started. But the more the number of single and accurate experiments is increased, the more solid will be the foundation of the whole system of chemical doctrine.

It would exceed the bounds I have prescribed myself, were I to extend these rules any farther. They are too numerous to be brought together in a small compass. He who wishes to devote himself to practical Chemistry, must of indispensible necessity exercise his intellect with reading and meditating the best models of investigation in the more modern chemical authors, and gather from them himself the best rules for the art of observation in Chemistry, and thus acquire the aptitude for making similar experiments upon a regular plan and with advantage, and for judging of them upon rational principles.

In like manner as a child does not learn to walk without previously falling, so all experiments that are instituted will not succeed. This however must merely be considered as a natural consequence of the imperfection of our nature, and not deter us from pursuing our course; as every error may prove instructive, if we do but endeavour to investigate its cause. If therefore an experiment fails, we should consider and turn over in our minds the results and consequences of it, as much as if it had succeeded, on the one hand, with a view to discover the cause of the cross result, and on the other, to investigate whether some advantage nevertheless may not be derived from it: for it has often happened that an experiment that has failed, has been more valuable and instructive than if it had succeeded according to our wishes. In such cases, therefore, it is best to begin the operation afresh, and in the course of it to redouble our attention, in order that we may proceed with the greater caution and prudence, and to have a watchful eye to the most minute occurences, to the end that our scope may be successfully attained.

PART

# PART II.

## MIXED CHEMISTRY.

IN the former part of this Work we treated of *pure* Chemiſtry, which is confined to the general doctrines of this Science, exhibiting withal a general view of the ſubjects, and deſcription of the inſtruments and operations of the art. In this ſecond part we proceed to ſhew the influence of Chemiſtry upon various Arts and Sciences, as under the denomination of *mixed** or applied Chemiſtry, it teaches the application, on the one hand, of bodies both natural and artificial to the various occaſions and purpoſes of life, and, on the other, of the general doctrines laid down in the former part, to the explication of the various phenomena of Nature. Agreeably to this view of the ſubject, we ſhall divide mixed Chemiſtry into *Technical*, *Oeconomical*, and *Pharmaceutical*; and, laſtly, *Phyſical* or *Philoſophical* Chemiſtry.

* We have ventured to introduce this term as a proper ſubſtitute for the *Chemia applicata* of the modern German writers, (in their language "angewandte Chemie") oppoſing it to the *Chemia pura*, or pure Chemiſtry, in the ſame manner as mixed mathematics are frequently oppoſed to pure mathematics. [E].

# BOOK. I.

## TECHNICAL CHEMISTRY.

UNDER this appellation are comprized thoſe chemical operations, by which a great number of natural bodies are, in different arts and manufactures, ſome of them obtained and produced, and others again wrought up into utenſils, and thus enhanced in value, and, finally, in divers ways adapted to the various occaſions and purpoſes of life. Hence it is evident, how great an influence an extenſive chemical knowledge of natural bodies has upon what is termed *Technology*, or *Political Oeconomy*; a ſcience which comprehends every ſpecies of art, handicraft and manufacture.

But as much as natural bodies, taken collectively, differ from each other with regard to their properties, ſo varied likewiſe, with reſpect to their final deſtinations, are the products obtained from them by the ſpagyric art. This part of the *Chemia applicata*, therefore, may be properly arranged under different heads or chapters, and may be ſubdivided into *Halurgy*, *Lithurgy*, *Hyalurgy*, *Metallurgy*, *Zymotechny*, *Phlogurgy*, and laſtly, ſuch operations as have for their object the *changing of the ſurfaces of bodies*.

## CHAP. I.

### HALURGY, or the Operations performed upon Salts.

HALURGY, or the doctrine of ſalts, treats of the various differences ſubſiſting between theſe two ſubſtances; of the methods of procuring, purifying, and variouſly compounding them, with a view to produce new ſpecies; and alſo of their principal properties, as well in their ſimple as in their compound ſtate.

This doctrine is of the greateſt importance, as upon an acquaintance with it is founded the whole ſcience of Chemiſtry. It is ſcarcely poſſible to point out an inquiry into natural bodies, in which it is not neceſſary. The knowledge of ſalts, therefore, and of their effects upon other bodies, ought always to be the firſt object of the Chemiſt's attention. Metals alone excepted, we may boldly affirm that all other bodies contain ſome portion of them. They are conſequently diffuſed through every department of Nature, a circumſtance, from which the indiſpenſible neceſſity and extreme activity of theſe bodies may be readily inferred. Their properties are very manifold and various, as will be made to appear in the following pages. Every particular that is remarkable and neceſſary to be known with reſpect to the diſtribution and claſſification of theſe ſubſtances has been already mentioned in the firſt part of this Work.

By *Salts*, are underſtood ſuch bodies as have a peculiarly acrid taſte, and are more or leſs ſoluble in water. Of the moſt ſimple kinds of ſalts, the greateſt part are always found in a liquid ſtate. The compound kinds are generally ſeen in a concrete form, and in cryſtalline figures, which in every one of them are different.

The *Acid* ſalts are to be met with in all the three kingdoms of Nature; but differing from each other, with reſpect to their conſtituent principles, in each particular kingdom, as well as among themſelves. The *liquid* acids are the pureſt. Theſe ſeem to conſiſt more of the fluid elements, for which reaſon they can hardly ever be obtained in a concrete form. The *ſolid* and concrete acids are com-

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monly combined with other ſubſtances, which impart ſolidity to them; though at the ſame time the acid in this mixture is predominant. The general properties of acids are, that when mixed with alkalies, they form neutral ſalts; that they diſſolve abſorbent earths and metals; impart a red colour to various blue juices extracted from vegetable ſubſtances; and that they precipitate all bodies diſſolved in alkaline ſalts. They may be diſtinguiſhed with the greateſt certainty from all other kinds of ſalts by their acid taſte.

With reſpect to the *liquid* acids, it has been obſerved that they conſtantly differ from each other in point of *ſtrength*. This difference may be made to appear: Firſt, by the quantity of lixivial ſalts ſaturated by them: Secondly, by the diſſolving power they exerciſe on theſe ſubſtances: Thirdly, by glaſs areometers; but finally, and with the greateſt certainty, by weighing a given meaſure of them in a conical glaſs that runs narrow towards the top, and comparing them with common water, taken as a ſtandard. With regard to their power of combining with different bodies, the degrees of ſuperiority of one over the other, a ſuperiority which has been aſcertained by repeated experiments, are worthy of obſervation.

The liquid and purer *mineral acids* are diſtinguiſhed from moſt of the acids of the other two kingdoms, by being leſs liable to be deſtroyed by fire, by a greater degree of gravity, by being more eaſily concentrated, by aſſuming a greater proportion of the matter of fire, when treated in that element, and conſequently acquiring a greater degree of acrimony*, and, in fine, by not being loaded as much as the other acids are, with mucilaginous and oily particles. Theſe properties however may be altered in various ways by the union of theſe acids themſelves with other bodies. Phlogiſton is capable of imparting to them a greater degree of volatility than they had before. When combined with fixed bodies, moſt of them are able to ſuſtain an intenſe heat; and by being intimately united with the former ſubſtance, they may be made to aſſume an aereal form. In ſtrict propriety they ſhould be claſſed among the ſimple ſalts, as no art has been able to decompoſe them and ſeparate them into their conſtituent parts. The *concrete* and more impure acids indeed, produced from certain bodies, taken from the mineral kingdom, plainly evince by their very dryneſs, that they are combined with other ſubſtances, and conſequently form exceptions to

* This ſeems to proceed from their being more eaſily dephlegmated than the acids of the other two kingdoms. As to their aſſumption of the matter of fire, it is merely hypothetical, and at beſt, a very free aſſumption of the author's. [E]

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this rule, and sufficiently explain what has been before advanced concerning them.

In the order of mineral* acids, the *Vitriolic* justly claims the precedence. This acid when united with the fixed alkaline salts, produces various bitter neutral salts; and, when combined with volatile alkali, *Glauber's sal ammoniac.* Combined with calcareous earth, it produces *Selenites* or *Gyps*; with *Terra ponderosa*, regenerated *Heavy Spar*; with magnesia, *Sal Catharticus amarus*; with the earth of alum, *Alum*; and by an intimate union with phlogiston, it forms *Sulphur*. It renders several metallic substances refractory, which are otherwise of easy fusion, and usually imparts to the volatile a greater degree of fixedness. From its union with the pure matter of fire it acquires, when in a concentrated state, the property of smoking, so as in the open air to emit white vapors in abundance.

It is produced in great quantities by means of fire, from the common martial vitriol, merely by distillation, without any addition. The common green vitriol is made use of for this purpose, as it is to be met with at a low price, and as this acid is easiest extracted from it. With respect to the operation itself, the following particulars should be attended to. First, the vitriol must be calcined in an iron or earthen vessel, till it appears of a yellowish red colour; by this operation it will lose half its weight. This is done in order to deprive it of the greatest part of the water which it has attracted into its crystals during the crystallization, and which would otherwise in the ensuing distillation greatly weaken the acid. As soon as the calcination is finished, the vitriol is to be put immediately, while it is warm, into a coated earthen retort, which is to be filled two thirds with it, so that the ingredients may have sufficient room upon being distended by the heat, and thus the bursting of the retort be prevented. It will be most adviseable to have the retort immediately enclosed in brick-work in a reverberatory furnace, and to stop up the neck of it till the distillation begins, in order to prevent the materials from attracting fresh humidity from the air. At the beginning of the distillation the retort must be opened, and a moderate fire is to be applied to it, in order to expel from the vitriol all that part of the phlegm which does not taste strongly of the acid, and which may be received in an open vessel placed under the retort. But as soon as there appear any acid drops, a receiver is to be added, into which has been previously poured a quantity of the acidulous fluid which has come over,

* According to M. *Berthollet*, volatile vitriolic acid is nothing else than common vitriolic acid holding sulphur in solution. [E]

in the proportion of half a pound of it to twelve pounds of the calcined vitriol, when the receiver is to be secured with a proper luting. The fire is now to be raised by little and little to the most intense degree of heat, and the receiver carefully covered with wet cloths, and (in winter time) with snow or ice, as the acid rises in the form of a thick white vapor, which towards the end of the operation becomes hot, and heats the receiver to a great degree. The fire must be continued at this high pitch for several days, till no more vapor issues from the retort, nor any drops are seen trickling down its sides. In the case of a great quantity of vitriol being distilled, M. *Bernhard* has observed it to continue emitting vapors in this manner for the space of ten days. When the vessels are quite cold, the receiver must be opened carefully, so that none of the luting may fall into it. After which the fluid contained in it, is to be poured into a bottle, and the air carefully excluded. The fluid that is thus obtained, is the *ordinary oil of vitriol*, of which *Bernhard* got sixty-four pounds from six hundred weight of vitriol; and, on the other hand, when no water had been previously poured into the receiver, fifty-two pounds only of a dry concrete acid.

The vitriolic acid is moreover obtained from sulphur, a process which is at this time carried on in large quantities in various manufactories in England and Scotland. On this account, the acid thus obtained, is by foreigners called *English* oil of vitriol. The chief of the process consists in burning sulphur with the addition of nitre in large close vessels; in which same vessels, the acid resulting from this operation is received, and afterwards concentrated. According to the *Laboratory laid open*, one part of nitre must be added to five parts of sulphur. *De la Follie*, however, speaking of another person who likewise procured it in large quantities, assures us that he mixed only one part of nitre with nine parts of sulphur. Portions of the mixture are successively ignited in a large ladle shaped like a spoon, and are burned in balloons or globes of an immense size, in which is contained a small quantity of water in the act of evaporation. Lastly, the fluid which is now strongly impregnated with the acid, is evaporated away to a certain degree. *Ferber* informs us that the large glass balloons are no longer used on account of their brittleness, and that very spacious leaden globes are employed instead of them. It is also reported that the putting of water into the globes is now disused, instead of which, the vapor of boiling water, which is contained in another vessel, is conducted to the detonating sulphur by means of a tube soldered to the globe; by this apparatus a stronger acid must necessarily be obtained; and the air in the globe is less heated and rarefied.

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In the upper cavity of the globe, there is, it ſeems, another aperture, which may be ſhut very cloſe by means of a ſcrew, and is ſometimes opened for the purpoſe of admitting freſh air. In the Engliſh manufactories, where their operations are conducted with great ſecrecy, ſeveral of theſe leaden globes, it is ſaid, are placed in a row cloſe to each other. This acid, after it is purified, does not differ eſſentially from that which is obtained from vitriol.

This acid may alſo be ſeparated from alum by diſtillation, but in very ſmall quanties only, becauſe the vitriolic acid attracts the earthy baſis very ſtrongly. As alum moreover is dearer than vitriol, this operation of courſe cannot be attended with any advantage, and is therefore never attempted.

The acid obtained from vitriol by diſtillation in the manner deſcribed above, may vary in point of ſtrength; the whole difference however entirely depends on the proportion in which the vitriol has been deprived of its water of cryſtallization by the preceding calcination, i. e. whether it has been burned till it has acquired a white, yellow, or a red colour. Hence the acid has different names given to it. If the vitriol be ſubjected to diſtillation in its natural ſtate, i. e. only calcined to whiteneſs, there comes over in the beginning merely a white acidulous fluid, which has been termed *phlegm of vitriol*, (Phlegma or ros vitrioli.) The ſubſequent and ſtronger acid, viz. that which is obtained in the beginning of the operation from the vitriol burnt to a yellow colour, is called *Spirit of Vitriol*. But the acid that comes over laſt, or that which diſtills from the vitriol when calcined to a red colour, is called *Oil of Vitriol*, on account of its being rather of a thick conſiſtence. That portion of the oil of vitriol which on this occaſion comes over laſt of all, has the peculiar property of immediately concreting into a ſolid ſaline maſs, in conſequence of having parted with its water which has been previouſly expelled by the fire: on this account it is termed *Glacial oil of Vitriol*, and conſequently is the ſtrongeſt vitriolic acid that can be made*.

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* As we have not hitherto been able to obtain a concrete and ſolid vitriolic acid from ſulphur, M. *Dollfuſs* was once inclined to think that the fuming property of the vitriolic acid was owing to ſome peculiar ſubſtance contained in it; for after having deprived the common vitriolic acid of this matter, he made a great many experiments with the acid, and could never give it the ſame property again; neither was he able to impart this faculty to the ſtrongeſt vitriolic acid that he could procure. He has ſince, however, altered his opinion on this ſubject, as he found that the vitriolic acid, when it has loſt the dry ſalt abovementioned, loſes ſomewhat of itpecificsfic gravity; in

As by the method above described four different acids of vitriol are successively obtained by one continued distillation; so, on the other hand, a *spirit* of vitriol may also be produced at once by a particular distillation from vitriol calcined to whiteness, in case that the whole of the fluid that comes over on this occasion is taken together without making any separation; and so likewise may an *oil* of vitriol be obtained from vitriol burnt to a red colour by a distillation made for this purpose. Thus from one part of oil of vitriol mixed with from three to four parts of distilled water, may be acquired a spirit of vitriol fit for common use; and, on the contrary, an acid that came over weak in the first distillation, may be rendered stronger and equal to *oil*, by abstracting the watery part in a retort.

As this acid, on account of its specific gravity and fixity, requires a strong fire for its expulsion, it may of course be very easily freed from all its water and concentrated, but from these very properties too, it proceeds that in its forcible expulsion from the fire, a large quantity of the matter of fire is combined with it, a circumstance upon which are founded some of its most peculiar qualities. Hence it proceeds that when exposed to the open air it smokes; and that when mixed with water, or other (especially inflammable) fluids, it grows extremely hot*. Now as its attraction to the pure matter of fire is hereby evinced; so likewise the dissolving power it exerts upon all substances containing phlogiston, as also the circumstance of its being tinged with a light or dark brown, or black hue, in proportion to the quantity of this substance, originates from the same cause. This colour, therefore, in any strong vitriolic acid, is a sign of a contamination of this nature, as it originally distills over of a bright colour, which however is commonly rendered dark by some of the luting falling into the liquor, or else by the pitch with which the earthen stoppers of the bottles containing it are cemented.

In case however of the vitriolic acid being rendered impure, either from this or any

in consequence of which discovery he now thinks that the most concentrated acid of vitriol, and that which is freest from water, goes over first in distillation, and after this has been drawn off from it, the vitriolic acid remains in a state in which it does not undergo any farther concentration. [D]

* From a review of M. *Dollfuss's* experiments referred to above, and a collation of them with those of other Chemists who have written on this subject, it appears somewhat probable that the fuming property of vitriolic acid proceeds from a high degree of dephlogistication and an union with pure air. M. *Westrumb*, indeed, (*Chemischa Ann.*) pretends that he has dissolved gold, silver and mercury, in the aerated vitriolic acid: but his acid was in all probability impure; as the experiments have been repeated without success. It is aerated by being distilled over manganese. See also *Hermstadt*, ibid.

any other accidental circumſtances, the beſt method of diveſting it of any impurity is by a freſh diſtillation. This is performed by means of a glaſs retort, which ſhould be buried ſomewhat deep in the ſand, and urged by a violent fire. The watery fluid which firſt diſtils over on this occaſion, may be received in a ſeparate veſſel, and another fitted on the inſtant the ſtrong acid begins to come over. By this means the acid is procured in its pure ſtate, and ſuch as it is required to be for accurate and exact chemical experiments.. There is another way propoſed by ſome, which however is very defective, of purifying a dark-coloured oil of vitriol: this conſiſts in merely boiling it up in a glaſs retort, and ſuffering it afterwards to grow cold, and to clear itſelf ſlowly and by degrees. By this proceſs the phlogiſtic particles are, as it were, burned and deſtroyed by the acid, and ſeparated from it in the form of fine and ſubtile earthy particles. The acid, it muſt be confeſſed, becomes colourleſs and limpid, like water; it may nevertheleſs contain various extraneous particles, which cannot by this means be ſeparated from it. Upon a ſimilar decompoſition of the combuſtible matter is founded alſo the following method of purification: viz. from half an ounce to ſix drachms of nitre are mixed with one pound of dark-coloured oil of vitriol, and the mixture is heated to the boiling point, or till the dark colour diſappears. In each of the latter caſes, the vitriolic acid is at the ſame time rendered impure in another way. On rectifying the oil of vitriol, as well as in the ſecond purification of it, there is found an earthy ſaline ſediment, which is more or leſs abundant, in proportion to the impurity of the oil. In the *Nord-hauſen* and other ſimilar oils of vitriol which are produced by the diſtillation of vitriol, this kind of impurity is uſually very trifling: but in the Engliſh oil of vitriol it is very conſiderable, on account of the acid's being prepared without diſtillation, and, indeed, in the way in which that is prepared, it is poſſible for contaminations of various kinds to take place. We are informed by *Gaubius*, that the reſiduum of an oil of vitriol, which he examined after diſtillation, conſiſted of Glauber's ſalts, and alum, mixed with particles of iron. I have myſelf detected in it vitriolated tartar ſuperſaturated with vitriolic acid.

The vitriolic acid, although it be concentrated in the higheſt degree, and diveſted as much as poſſible of all its watery part, nevertheleſs always retains a ſtrong attraction to water: and this will even be exerted by the acid in proportion to the degree of its concentration: hence it is that the glacial oil diſſolves ſo ſoon if the air be not excluded with all poſſible care: and hence too the matter of fire will be expelled from the oil of vitriol by the air, and the oil at the ſame time acquire a very conſiderable addition to its weight. This explains the cauſe why it

is so difficult to procure the vitriolic acid when pure and strong in a concrete form. Indeed but two instances of it can be given, and those by no means durable; one in the congelation of *oil* of vitriol, and the other in what is called the *glacial* oil, which is produced by the highest degree of concentration. Besides these, *Baldasari*, indeed, pretends to have discovered in the neighbourhood of a volcano, a pure and solid vitriolic acid, from which at least alkaline salt did not precipitate any earthy matter; but there is great reason to doubt of the perfect purity of this substance.

Of all the liquid mineral acids, the vitriolic is capable of the highest degree of concentration, and consequently of acquiring the greatest specific gravity. Moreover it has a stronger attraction to various bodies than the rest of the acids have; whence it is also able to expel the latter from those bodies viâ humidâ; and consequently is esteemed to be stronger than other acid. To this rule, however, there are certain exceptions to be observed, viz. that it has the power of expelling the volatile acids only in the dry way; while, on the other hand, it appears that it is itself expelled in its turn by means of fire by the more fixed acids, such as dephlogisticated arsenic, and the phosphoric acids. In like manner it is in its turn, partially at least, separated by a redundancy of nitrous acid from fixed alkali, from which however it always expells the nitrous acid in the dry way. It can therefore be only conditionally accounted the strongest of the mineral acids, since it does not exhibit this faculty in all, although it does in most instances.

As great as the power and fixity of this acid is, it may nevertheless by a slight union with phlogiston be so far altered, as to give place to all the other weaker acids, and cede to them the bodies with which it is united. In this state it bears the name of *volatile vitriolic*, or *sulphureous* acid, and may be obtained as well in a natural as in an artificial way.

Nature produces this composition in the environs of divers hot springs, as also near volcanos which have ceased to burn: where however it cannot be conveniently collected. This acid is always to be obtained by art, when the vitriolic acid, during its distillation by fire, has an opportunity given it of combining with a certain portion of inflammable matter. Now this takes place in each of the following cases: when sulphur is fired either under a glass receiver, a large alembic, or any other wide capacious vessel, in which operation the greatest part of the phlogiston of the sulphur is destroyed by the inflammation and carried up into the air, and consequently the acid of the sulphur is for the greatest part divested of it. This acid will however, on such occasion, retain some small portion of phlogiston, which it will also keep on its attracting the moisture of the atmosphere, (in

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consequence of which the vapor of the burning sulphur is converted into a liquid), and even on its being saturated with alkaline salts. This altered acid is produced likewise, when in the distillation of vitriol, the retort by some accident happens to crack, by which means the phlogiston insinuates itself into the retort, and unites with the acid as it comes over. The same effect ensues when any inflammable substance, such as oil, tallow, pitch, wax, resin, coals, &c. is mixed with the concentrated acid of vitriol, and distilled; and this is the reason that all oil of vitriol that has acquired a brown colour, as also crude vitriol in the beginning of the distillation, yield a similar volatile acid. On this sulphur also depends *Sehl's* spirit of sulphur, which is produced from a *hepar sulpharis*, prepared with fixed alkali, quicklime, sulphur, by the admixture of oil of vitriol. To how great a degree of volatility the vitriolic acid, which is otherwise of so fixed a nature, can be brought by means of inflammable matter thus combined with it, we learn by the following instance: viz. that when a fixed alkali i saturated with this volatile vitriolic acid, so as to form with it a neutral salt, it may be separated from the alkali again by any of those acids, which otherwise are not able to expel the vitriolic acid from its basis.

Now, though the sulphureous acid be very volatile, yet it may be very soon divested again of this high degree of volatility. This acid being diluted with water, and for some time exposed to the open air, will manifest its superior attraction to phlogiston, by depriving the now weakened vitriolic acid of it, and leaving this latter substance in a pure state, though at the same time weakened by the admixture of water, from which it may now be freed by evaporation.

When, on the contrary, the vitriolic acid, entirely divested of any watery substance whatever, is more intimately combined with phlogiston, there arises from this union, *Sulphur*: a solid body, of which more will be said in another place.

It is not commonly to be met with in the air, as has been formerly supposed. And even if in consequence of the roasting of metals, or the cleaning of woollen stuffs with brimstone, it be sometimes occasionally carried into the air, it will not remain there any considerable length of time, but will soon be precipitated to the earth again, together with the rain. Indeed there is no evidence whatever of its being constantly present in the air. So that these observations entirely subvert the ancient hypothesis of its being the universal acid, from which all other acids originate. It consists of the simplest elements in Nature, is undecomposable by art, and cannot

cannot therefore be combined by art, where it does not already previoufly exift: for with its actual compofition we are entirely unacquainted.

The fecond mineral acid, viz. the *Nitrous*, differs from all the other acids, by an odour peculiar to itfelf, and which is not to be defcribed, and by the red vapors exhaling from it in its concentrated ftate. From its combination with alkaline falts are produced various detonating neutral falts. From calcareous earth it may be entirely expelled by an intenfe fire. It diffolves iron with a brown colour.

It is no where to be met with native in an uncombined ftate, but is produced by Nature on the furface of the earth only, where it is commonly found combined with lime or magnefia, though it is frequently united with fixed alkali fo as to form a genuine nitre. From the time that the philofophic world has ceafed to be ftartled at this heterodox pofition, there is no longer any doubt made of the exiftence of native nitre, efpecially as *Bowles* in his *Introduction to the Natural Hiftory and Phyfical Geography of Spain*, affures us, that the nitre in that kingdom, in like manner as in the Eaft Indies, is found ready formed with its bafis whole and entire, in the earth, from which it is elixated by mere boiling, without any addition whatever. Either from this native nitre, or from the artificial fort, of which we fhall make mention hereafter, the nitrous acid muft always be obtained by the affiftance of art. As this acid is fo ftrongly united with the alkaline falt, that it is rather deftroyed than expelled by the mere action of fire, another body muft be called into to our affiftance, by which this ftrong union can be diffolved. Now to produce this effect, the acid of vitriol particularly, either in its free ftate, or combined with other bodies, is found to be adapted. When the mere concentrated acid of vitriol is employed, *Glauber's Smoking Spirit of Nitre*, (Spiritus Nitri Fumans Glauberi) is produced in the following manner: two pounds of dry purified and pulverized nitre are put into a coated ftone or glafs retort, capable of containing from five to fix pounds, upon which is poured one pound of oil of vitriol through a glafs tube, that reaches as far as to the belly of the retort; immediately after this it is to be placed either in a reverberatory furnace, or a fand-pot, and a receiver that fits it exactly, fixed to it. For the purpofe of clofing the junctures of the veffel, the fat lute is employed here with particular advantage, as it will not be fo eafily affected by the vapors of this acid. In the beginning of this operation, a gentle fire is to be made, which is to be increafed gradually, and with great caution, for by too great hafte at the commencement, the whole mixture would be thrown into an impetuous motion with effervefcence. Towards the end

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of the operation, the fire may be increased, and continued in the same degree till no more vapors are observed to issue from the retort, and the receiver no longer feels warm. When the whole of the distilling apparatus is entirely cold, the receiver is to be carefully opened, and the strong liquor contained in it is to be poured into a glass phial provided with a ground glass stopper, which for the sake of greater security, may be covered with pitch. For making the common *aqua fortis*, to one part of saltpetre are added two or three parts of the residuum left after the distillation of oil of vitriol, or one part only of vitriol calcined to a light red colour, and the whole distilled in a stone retort, by a naked fire. Now according to the strength the aqua fortis is to have, either a quantity of water equal in weight to the nitre, or to half, or a quarter of that weight, or, in fine, no water at all, is to be previously put into the receiver. Besides this method, a weak spirit of nitre may also be obtained by using vitriol calcined to whiteness only, or even not calcined at all. In this case the acid, which comes over in distillation, is diluted by the water contained in the ingredients; though this scope may be better obtained in the preceding manner. Burnt alum, moreover, may be made use of for the expulsion of the nitrous acid.

It must be likewise remembered that the nitrous acid may moreover be expelled by all sorts of clay, as also by the addition of various kinds of vitrifiable earth. Clean pebbles, quartz in the form of sand, pieces of broken china, and stone-ware, as likewise glass when pulverized, and mixed with the nitre in the proportion of six to one, will by the assistance of a violent fire, though always imperfectly, expel its acid *.

This acid may be moreover disengaged by means of white arsenic, by mixing this substance with an equal quantity of purified saltpetre, and distilling the mixture in a retort with some water in the receiver, when a *blue aqua fortis* is obtained. This observation seems to have been first made by *Kunkel*.

In the former of the abovementioned cases, the expulsion of the nitrous acid proceeds entirely from the stronger attraction of the acid of vitriol to the fixed alkali of the nitre, which acid on this account unites with the alkali, and consequently sets the nitrous acid at liberty, which is then expelled by fire. And in those cases too, where instead of pure acid of vitriol, vitriol itself, or alum is added, the separation ensues from the very same cause.

* From *Demachy's* description, it appears that in France the nitrous acid is always extracted by means of clay.

The other caſe, in which this acid is expelled by argillaceous or ſiliceous ſubſtances, muſt in like manner depend on the combining power or mutual affinity of theſe bodies; but the efficient cauſe ſeems to lie in the alkaline ſalt, and at the ſame time in the violence of the fire applied. The alkali without doubt has a great affinity with the nitrous acid, as being a volatile acid, but it poſſeſſes alſo, when aſſiſted by fire, a ſtrong attraction for ſiliceous earth, as the eaſy ſolution of this earth by it in fire, plainly evinces. Hence it follows in the preſent caſe, that when nitre is treated in the fire together with ſiliceous earth, that the alkali of the former ſubſtance by the aſſiſtance of the fire, unites with the latter, by which means the acid being of a more volatile nature, is forced to give way; it has been obſerved at leaſt, that the nitre parts with ſome, if not the whole of its acid. *Monnet* affirms, that the reſiduum of a diſtillation of one part of nitre and three parts of flint reduced to a fine powder, which had yielded a ſmoking ſpirit of nitre, gave out after it was elixated, a ſolution which had an evidently alkaline taſte, tinged the juice of violets green, and exhibited, when mixed with acids, a gelatinous coagulum or precipitate. At another time the uncombined alkali diſcovered itſelf alſo by a manifeſt efferveſcence, which plainly indicates that the alkali of the nitre had united with the ſiliceous earth. The effect of clay likewiſe in this operation, ſeems deriveable from a ſimilar principle, or at leaſt, partly ſo; for it cannot be denied that moſt clays have occaſionally a portion of vitriolic acid combined with them, and that conſequently this acid muſt in ſuch a caſe be brought into action likewiſe.

In the third caſe, the arſenic being of an acid nature, acts upon the alkali of the nitre, and, on the other hand, gives up to the nitrous acid, now on the point of ſeparating from it, its portion of phlogiſton, with which the acid immediately unites; whence ariſes the increaſe of its elaſticity. The fine blue colour of the acid when procured in this manner, originates alſo, partly from a certain portion of phlogiſton taken up by it from the arſenic, and partly from the dilution of the acid, by the water preſented to it in the retort. For a concentrated nitrous acid of an intenſely red colour, has been freequently obſerved to become blue merely by being diluted.

Excluſively of theſe methods, it is alſo remarkable that nitrous acid may even be expelled either from the common, or cubic nitre, by the marine acid alone. When nitre is mixed with from eight to nine times its quantity of ſtrong ſpirit of ſalt, and diſtilled, an acid is obtained according to *Marggraf*, which chiefly conſiſts of the nitrous acid, but which alſo contains ſome portion of the marine acid.

This effect probably depends on the superabundant quantity employed of the marine acid, by which this acid is made to exert a power which it does not possess according to its natural degree of attraction towards the alkali.

In distillation the nitrous acid may be rendered impure in two ways. First, by the admixture of a portion of vitriolic acid, which may be forcibly carried over with it: and, secondly, from the nitre which is employed, containing some common salt, the acid of which comes over along with it. The inconvenience in the first case may be removed by dissolving in a small quantity of aqua fortis, as much fine cupelled silver as it will take up. Of this solution, so many drops must be added to any quantity ad libitum of the aqua fortis, till the aqua fortis ceases to be rendered turbid by it. Now when in the space of a few hours, the disengaged calx has subsided to the bottom, it is separated from it by filtration. This precipitate will be a luna cornea, because the marine acid has united itself to the silver. The aqua fortis purified by this method, is called *precipitated* aqua fortis, and may be used without any farther preparation for dissolving silver, or for separating it from gold. The liquor however must undergo the strictest examination, and the greatest care must be taken that the smallest portion of silver, which may yet remain in this kind of aqua fortis, and which is called the *Hinterhalt*, or arrearage, be not overlooked. It is therefore a safer method to distil it to dryness in a retort. When the impurity proceeds from the acid of vitriol, and it is known with certainty that there is no marine acid combined with it, in this case the acid needs only be distilled over a small portion of purified nitre, by which the vitriolic acid will be separated on the same principle, as the disengagement of the whole of the nitrous acid was first effected upon. Should it however be at the same time rendered impure by the admixture of the marine acid, the precipitation by means of the solution of silver must of necessity be previously employed. The best way of rendering aqua fortis serviceable, that is too weak, and consequently not fit for use, is to add to it some very strong acid; for the concentration of this acid by means of evaporation, is inconvenient on account of its volatility, and sometimes also when the quantity is small, will not answer the expence. The more concentrated and divested of aqueous particles this acid comes over in distillation, the more igneous matter from the fire will unite with it. And from this cause arise its eminently corrosive property, the heat and flame, which it exhibits with many bodies, as also its attraction to water, and the red colour of its vapors. This position, I must own, is not altogether orthodox, at least certainly not with regard to the red vapors, which are commonly ascribed to phlogiston; I shall however briefly give the reason, why I entertain

ſuch heterodox opinions on this ſubject. It is certain that the red vapors of the nitrous acid are equally accidental with the white vapors of the vitriolic: for they may both of them part from theſe vapors without ceaſing to be the ſame acids as before, and without loſing their other properties: in the caſe of the nitrous acid too, theſe vapors may be greatly augmented by the addition of certain bodies, conſequently they muſt originate from ſome other ſubſtance. During the diſtillation of the ſpiritus nitri fumans, a very remarkable phenomenon occurs, which may decide the point at once. It is as follows: This acid in the beginning comes over in the form of vapors of a deep red colour; on continuing the proceſs, theſe vapors decreaſe, and the acid that comes over, emits vapors of not ſo deep a hue: but when towards the end the ſtrongeſt fire is employed, the reddiſh colour, together with the denſe deep-red vapors, make their appearance, and continue to the end of the operation. Now whence do the red vapors proceed in this laſt period? In all probability, from the ſame cauſe which occaſioned them in the beginning. It is commonly aſſerted that they originate from phlogiſton. I will allow this for a moment, but at the ſame time beg leave to aſk, why does this phlogiſton act more weakly towards, and during the middle period of the operation, and with greater force again towards the end? If in fact there be phlogiſton in the mixture, and it has began to operate, it cannot ceaſe to act, till it be totally exhauſted; and this muſt neceſſarily have happened within the firſt period. But as the red vapors appear again in greater quantities in the latter period, a freſh portion of phlogiſton muſt have been added, which however is not the caſe; for there is no longer any at this time in the compound, and it is alſo impoſſible that it ſhould penetrate into the body of the retort, from the outſide of it. Conſequently, as the laſt red vapors cannot originate from the phlogiſton, it may alſo with great reaſon be doubted whether the firſt can derive their colour from it. But whence then do they ariſe? To this queſtion, I will anſwer as well as my ſlender knowledge of the ſubject will permit me: I grant that there may exiſt a phlogiſtic compound, either in the oil of vitriol, or elſe in the vitriol itſelf; but I maintain that the red colour which firſt appears on the expulſion of the nitrous acid, does not ariſe from the phlogiſton in toto, but only from one of its conſtituent parts, viz. from the pure matter of fire, that here is developed in conſequence of the univerſally acknowledged ſtrong action of the nitrous acid upon all inflammable matter, which is actually deſtroyed by it. As in the preſent caſe, this effect muſt take place at the very beginning, the red colour of the acid which come over, is of courſe immediately occaſioned by it, which colour, for want of more of the matter of fire, is not obſerved in the acid

that diſtills over in the middle of the operation. In the latter part of the proceſs, however, when the fire is raiſed to a conſiderable pitch, freſh matter of fire penetrates from the fire into the retort, unites with the concentrated acid in its paſſage, and imparts to it again the ſame red colour and vapors that are uſually exhibited by the acid that firſt comes over.

Should the following objection, which is founded upon experience, be urged againſt me, viz. that a weak nitrous acid, which emits no fumes at all, may eaſily be cauſed to emit red vapors, by only pouring it upon iron, zinc, or other metals; and that in this proceſs the phlogiſton is, beyond a doubt, expelled from the metals, and conſequently muſt occaſion the red vapors; I might juſt as well apply this very obſervation in favour of my own ſyſtem; but I muſt adduce farther proofs in ſupport of it. When iron, tin or zinc is diſſolved in the marine or vitriolic acid, a quantity of true and genuine inflammable air is obtained, which is generated by the expulſion of the phlogiſton from theſe metals. That phlogiſton, in its whole and entire ſtate, is preſent here, cannot be denied. But, when on the contrary, the ſame metals are diſſolved in the nitrous acid, inſtead of the acids beforementioned, no inflammable air whatever is produced. Whence can this difference proceed, but from the reaſon that the former acids do not act nearly ſo powerfully upon phlogiſton, as the nitrous acid does? They merely unite with it, but do not decompoſe it in the leaſt; for which reaſon it retains its inflammability. On the contrary, the action of the nitrous acid upon this ſubſtance is very different; as in proportion to the quantity of this acid, and to the activity reſulting from thence, it thoroughly decompoſes this matter wherever it meets with it, into its conſtituent elements. So that inflammable air cannot be produced by the ſolution of the abovementioned metals in the nitrous acid, becauſe there is no entire and undecompoſed phlogiſton in it, and conſequently the red colour of this air cannot originate from it, but only from one of the conſtituent parts of the *decompoſed and deſtroyed phlogiſton*,— viz. the pure elementary matter of fire. Another very evident proof of my aſſertion is founded upon an obſervation made by *Scheele*, who ſays in his *Treatiſe on Air and Fire*, page 80, that a portion of nitrous acid, which he had deprived of its red vapors by means of fire, and expoſed to the rays of the ſun in a phial of flint glaſs, was found three hours after to have filled the glaſs with red vapors. Hence *Scheele* infers the preſence of phlogiſton in the light—and I quite the contrary. As phlogiſton is incapable of penetrating glaſs, none of it can have entered the phial, and conſequently thoſe red vapors could not have originated from phlogiſton, but ſolely from the

pure

pure matter of fire. When fuming ſpirit of nitre is poured into a glaſs retort, and ſuch a quantity of it is drawn off by diſtillation with a gentle fire, that the remainder is limpid and colourleſs, like water; *dephlogiſticated nitrous acid* is obtained, which is diſtinguiſhed by the white vapors it emits when ſet in a warm place. In fact, it ſhould be kept in a dark place in a phial cloſed with a glaſs ſtopper, as otherwiſe it will be again phlogiſticated by the light of the ſun, and re-acquire its property of yielding red vapors. In the ſame manner may any other moderately ſtrong acid of nitre be dephlogiſticated, by diſtilling part of it off. What takes place here may be compared to what happens in the rectification of oil of vitriol, and in the ſeparation of the ſubſtance which gives it its ſmoking property. If it be heated by a fierce fire, it will again emit red vapors in the ſame manner as that which has been expoſed to the light of the ſun.

The nitrous acid is not poſſeſſed of the power of attracting water in an equal degree with the acid of vitriol; and nevertheleſs we much more rarely meet with the nitrous than the vitriolic acid, in a ſolid form. *Bernhard* appears to have been the firſt who obſerved this phenomenon. On the diſtillation of a very large quantity of nitrous acid, he ſaw, adhering to the inſide of the receiver, a dry ſolid ſalt, which was of a white colour, corroded every thing that came into contact with it, and emitted red vapours copiouſly on being expoſed to the air, wherein at length it was entirely diſſipated.—The ſpecific gravity too of this acid is inferior to that of the acid of vitriol, for which reaſon it can never be ſo highly concentrated as to be equal in this reſpect to the oil of vitriol. But its moſt remarkable property is its powerful operation upon all inflammable matter, upon which it acts as well in the humid as in the dry way, and decompoſes it into its conſtituent principles. On this account it may be uſed for the purpoſe of ſeparating phlogiſton from the various bodies with which it is combined. The neceſſary reſult however of this is, that the acid itſelf undergoes various changes in its properties, in proportion to the quantity of phlogiſton upon which it has acted. This obſervation brings us to the origin of nitrous air. The method of depriving this acid of its red vapors, and of reſtoring them again to it, has been already made mention of.

The notion which was formerly entertained by many, that the nitrous acid originates from the acid of common ſalt, and may be procured from it by the aſſiſtance of art, has been invariably found to be devoid of all foundation. The muriatic ſalt which is obtained along with the nitre itſelf in the boiling of nitre, has given birth to this opinion. That it ſhould derive its origin from the vitriolic acid, is by far more improbable and without foundation. The

production

production of true and genuine cryftals of nitre, on occafions where the vitriolic acid only has been ufed, indubitably always proceeds from the prefence of a latent nitrous acid. In the fame way probably we may account for the experiment in which cryftals of this falt were faid to have been obtained from vitriolic æther, by the addition of fixed alkali. Perhaps oil of vitriol prepared according to the Englifh method by means of nitre, was employed in making this naphta or æther, in which cafe this phenomenon may be very naturally explained without admitting any tranfmutation to have taken place*.

* Mr. *Cavendifh* has fhewn that the nitrous acid may be formed by taking the electric fpark in a mixture of three meafures of phlogifticated and feven of dephlogifticated air, or in weight, 1 part of the former and about 2,6 of the latter. It is to this important difcovery of Mr. *Cavendifh* that we owe our knowledge of the compofition of the nitrous acid, and from the ingenious obfervations of M. *Thouvenel*, that we derive our information in what manner Nature acts in the generation of it.

According to M. *Lavoifier*, nitrous acid confifts of nitrous air (its bafis) united with the oxygenous principle or the bafe of pure air, in the following proportions: 100 grains of dry nitrous acid confift of 64 grains of nitrous acid united with 36 of pure air deprived of its fpecific fire Nitrous air he confiders as a compound; 100 grains contain, according to his experiments, 32 parts of phlogifticated air, or mephitis, and 68 of pure air: confequently the abovementioned 64 grains confift of 20,5 grains of phlogifticated, and 43,5 of pure air. Hence, according to him, 100 grains of dry nitrous acid confift of $79\frac{1}{2}$ pure air, and $20\frac{1}{2}$ phlogifticated air. This calculation differs confiderably from the refults of Mr. *Cavendifh's* obfervation, which is owing to the different degree of phlogiftication of the nitrous acid employed by thefe two Philofophers in their refpective experiments: for Mr. *Scheele* obferved a great difference between the red and the colourlefs fpirit of nitre, the former containing much more phlogifton than the latter; and the acid which Mr. *Cavendifh* obtained, was, in fact, of the red fort, which may be called highly phlogifticated.

The manner in which Nature generates nitre, has been inveftigated by M. *Thouvenel* with great fagacity and precifion *. This accurate obferver found that the nitrous acid was conftantly produced, when he expofed chalk to a mixture of common and putrid air, or of putrid air, and dephlogifticated air. But when he made the putrid air pafs through lime water, it was never generated; he obferved it likewife to be rarely produced when he expofed quicklime or alkali to the abovementioned air.

Mr. *Kirwan* thinks that 100 grains of dry nitrous acid confift of 38,17 grains of fixed air, which he calls its acidifying principle, 57,06 of nitrous bafis, and 4,77 of phlogifton united to nitrous bafis. Nitrous bafis he ftates to confift of $\frac{1}{3}$ of phlogifticated and $\frac{2}{3}$ of dephlogifticated or pure air, both in a concrete ftate. He likewife fuppofes that 100 grains of nitrous bafis take up nearly 22 of phlogifton. [E]

* Viz. Memoires des Seav. Etrang. p. 126—128.

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The *marine* acid, which occupies the third place in the order of the mineral acids, is likewife diftinguifhed by a fmell entirely peculiar to itfelf, which can be perceived only, not defcribed. In diftillation, if it be combined with a fmaller portion of water than ufual, it will come over in grey vapors, which can fcarcely be retained. With fixed alkaline falts, it forms neutral falts, which decrepitate in the fire. When combined with volatile alkali, it produces fal ammoniac. When combined with calcareous earth, it may be evaporated indeed to a dry-concrete mafs, which however foon deliquefces again on being expofed to the air, and never parts with its acid when urged by fire. When united with certain metals, it communicates to them a deliquefcent property. Others again are rendered volatile by it.

This acid is no where to be met with in great abundance native, and in an uncombined ftate. By reafon of its great attractive power, it is every where united either with earths or alkaline falts. The greateft quantity of it is contained in common falt, from which therefore it fhould always be obtained. But as it cannot be expelled by the mere action of fire, this effect muft be accomplifhed chiefly by the intervention of the vitriolic acid by itfelf, or elfe of certain other bodies which contain it. According to the degrees of ftrength it has when thus produced, it bears the name of *Oil of Salt*, (Oleum Muriæ), *Fuming Spirit of Salt*, or fimply, *Spirit of Salt*. If it be required as highly concentrated as poffible, the common falt fhould be previoufly deprived of all its humidity, by making it perfectly dry over the fire, or by decrepitation: though whoever attempts to procure from this the *fpiritus nitri fumans Glauberi*, will find himfelf egregioufly deceived; fince in this cafe the acid paffes over fo copioufly in vapors, which vapors cannot poffibly be collected. It is therefore more advifeable to take the falt in a very moift ftate, or elfe, which is ftill better, previoufly to dilute the oil of vitriol, requifite for this purpofe, with water. With this view, fix pounds of common falt are to be put into a proportionably large glafs retort; upon this are to be poured four pounds of oil of vitriol, which has been previoufly diluted in a feparate veffel with four pounds of water; this is to be diftilled by a fire, which is to be gradually increafed, till at length when it is at its greateft height, no more vapors are feen to iffue from the retort, and the receiver is become cold. Vitriol itfelf cannot be employed with advantage for effecting this feparation; becaufe a great part of the marine acid is fo intimately united with the ferruginous earth in the vitriol, as not to be expelled from it by the fierceft fire. When vitriol therefore is ufed, a fmall quantity only is obtained of weak

marine

marine acid, which is moreover rendered impure by the admixture of iron. It is by far more advantageous to uſe alum in this operation, but it ſhould be previouſly deprived by means of fire of the water which it has attracted in its cryſtallization. With this is to be mixed an equal quantity of common ſalt, from which the acid is to be expelled by the requiſite degree of heat. In all theſe caſes, the expulſion of the marine acid by the vitriolic is effected on the principles already mentioned in treating of the nitrous acid. The marine acid is alſo very conveniently ſeparated from a highly concentrated bittern or mother-water of common ſalt, which has ceaſed to yield cryſtals, by adding to five pounds of it one pound of oil of vitriol diluted with two of water, and diſtilling it in a retort, in the manner propoſed by *Weber*.

This acid may likewiſe be expelled from common ſalt, by talc, ſand or clay, as being fixed earthy ſubſtances, in which caſe, the weight of theſe ſubſtances muſt be equal to twice that of the ſalt. But it is the ſame with reſpect to this ſalt as it is with reſpect to nitre, viz. the ſeparation is not ſo completely effected as it is by means of the vitriolic acid. The ſeparation depends on the combination of the alkali with theſe earths. According to *Marggraf*, the earth of alum likewiſe expels this acid; I am however rather inclined to aſcribe this effect to a latent portion of vitriolic acid contained in this earth*.

It may moreover be obtained from ſal ammoniac, by means of concentrated vitriolic acid. This method however, on account of its expence, is by no means adviſable. When the nitrous acid is employed for the production of the marine acid from common ſalt, the former ſubſtance muſt be uſed in a ſtate of the higheſt concentration, and in a double proportion, as is proved by *Marggraf's* experiments. This acid however is not abſolutely pure. It can never, or, at leaſt, in a very ſmall quantity only, be obtained from pure common ſalt, by the mere action of fire.

This acid is commonly of a yellow colour, which colour however is not peculiar to it, but is generally owing to the iron that it has carried over with it, either

* Arſenic however is not able to decompoſe common ſalt as it does nitre; becauſe it is too volatile, and contains more phlogiſton than the common marine acid is able to deprive it of. But if the arſenic be dephlogiſticated, and converted into arſenical acid, the marine acid may be very eaſily expelled by it in a red heat. (Vid. *Scheele's* Treatiſe on Arſenic, publiſhed in his works.) Common ſalt may be likewiſe decompoſed according to *Marggraf*, by the phoſphoric acid, and by phoſphoric ſalt. And according to Dr. *Crell*, the acid of fat likewiſe diſengages the marine acid from common ſalt. (Vid. *Crell's* Chemiſches Journal, T. II.)

The acid of tartar, though it is capable of (partially at leaſt) decompoſing digeſtive ſalt, does not diſengage the marine acid from common ſalt. (Vid. *Bergman* on Elective attraction, § 9. & 39.[E]

from the ſubſtances uſed for its expulſion, or from the common ſalt itſelf. That iron might be contained in theſe additional ingredients, it is eaſy to conceive; but the preſence of this metal in the ſalt itſelf is not ſo readily ſuſpected; which however, in conſequence of its being boiled in iron pans, is found to be conſtantly pregnated with it *.

Now as the Chemiſt muſt have every thing that is neceſſary to him for the inveſtigation of other bodies in its utmoſt ſtate of purity, it is likewiſe requiſite that he ſhould have this acid alſo as pure as poſſible. Now it may be freed as well from the portion of iron adhering to it, as likewiſe from the vitriolic acid commonly carried over along with it, by re-diſtilling it over a little common ſalt, by which means both theſe defects are removed at one and the ſame time. But, on the other hand, it is far more difficult to ſeparate from it by this method, the other metallic particles that may be volatilized together with it.

It poſſeſſes a very great affinity to water; for this reaſon it appears always fluid, and there is no experiment known, which evinces that its acid has ever acquired a ſolid form, unleſs it were in combination with ſome other ſolid body. It unites with phlogiſton indeed; but it never intimately combines with it. For this reaſon the phlogiſton of metals is not decompoſed by this acid, but it will produce phlogiſticated vapors, which are ſometimes inflammable. This acid in its uſual ſtate is always united with a portion of phlogiſton, of which, according to *Scheele*, it may be diveſted, if it be diſtilled over nearly the fourth part of its quantity of pulverized mangaueſe, whence it acquires the appellation of

* By way of limiting in ſome meaſure this poſition, it muſt be obſerved, that it is only when it is of a pale lemon-colour, and when by the application of re-agents it is diſcovered to contain iron, or when iron is actually precipitated from it in the form of a brown calx, that the marine acid owes its yellow colour to this metal. But this acid may ſometimes alſo appear of a much darker and nearly a brown colour, without any iron however being diſcoverable in it. This I have obſerved ſeveral times in marine acid prepared with concentrated acid of vitriol; of which, on its rectification over freſh common ſalt, nearly the fourth part in the beginning, came over of a browniſh hue, and accompanied with copious vapours, notwithſtanding which, upon examination, it exhibited no veſtiges of iron whatever. The whole of the acid that came over afterwards, was as colourleſs and limpid as water. [A]

M. *Dollfuſs* thinks that the yellow colour here ſpoken of, is rather to be aſcribed to a certain proportion of dephlogiſticated air, which this acid generally contains, and it would not be difficult to demonſtrate that this acid yields rather pure air than phlogiſton: for a candle put into a bottle containing a quantity of marine acid, will burn for a conſiderable time longer than it will in common air. [E]

*dephlo-*

*dephlogisticated marine acid.* The marine acid thus distilled from manganese, has a volatile smell, almost like that of the volatile sulphureous acid, but at the same time, (which is remarkable,) a very slight acid taste, notwithstanding which it dissolves leaf-gold very readily, without heat. Nearly half of the acid which first distills over, is of this kind; but the other half has the odour of common marine acid, and, though more acid to the taste than the former, does not dissolve gold *.

No one has as yet been able to produce the marine acid from any other acid, by transmutation: consequently, it is the mere production of Nature, and is chiefly to be met with in common salt †.

From the mere mixture of the nitrous and marine acids, arises a compound liquid, called *Aqua Regia.* For this purpose, they need both be only of a moderate strength; two parts of the former may be taken to one of the latter. Pure marine acid, indeed, is not absolutely requisite for this purpose; but, on the contrary, various neutral salts may be employed, which contain this acid, viz. sal ammoniac, common and digestive salt, mixed with three or four times their quantity of nitrous acid. With respect however to other effects, it is not quite so indifferent in what method aqua regia is prepared; since each of these different kinds will be distinguished by various adventitious properties. This

mixed

* The opinion that the marine acid which is able to dissolve gold is merely dephlogisticated, is extremely erroneous: because the marine acid in its dephlogistication evidently acquires a quantity of pure air, as will be more fully shown when we come to treat of aqua regia. [E]

† As to the composition of this acid, we have hitherto known little or nothing of it; and, for the little we know at present, we are indebted to the curious experiments made by the ingenious M. *Berthollet,* and related in the Journal de Physique. According to the experiments here alluded to, the marine acid seems to consist of a peculiar basis united with the oxygenous principle, (as it is termed by the French academicians:) and the dephlogisticated marine acid differs from the common, in containing an excess of this principle, or, to speak more properly, of pure air. This not only appears by the experiments of Messrs. *Berthollet* and *Pelletier,* but is farther confirmed by the observations of M. *Hermstadt.* Mr. *Kirwan,* however, (See his *Essay on Phlogiston)* thinks it is fixed air which mixes with the marine acid, as he supposes that it is fixed air that is contained in the calces of metals, and that the dephlogisticated air which is obtained by the calcination of manganese, proceeds from the attraction of this calx to the phlogiston of the fixed air, in consequence of which attraction, this latter substance is dephlogisticated. This assertion he endeavours to prove by several experiments, and especially by the failure of those of M. *de Morveau* and M. *Berthollet,* who tried in vain to combine dephlogisticated air directly with the common marine acid. [D]



The

mixed acid is the proper folvent of gold*, tin and antimony. For the two latter metals, however, the marine acid fhould be taken in a larger proportion than the nitrous†.

The aerated or dephlogifticated marine acid, or epimuriatic acid, is produced by diftilling the ordinary marine acid over manganefe, and other fubftances containing air, to which it imparts its phlogifton, at the fame time that it receives the air from them. With fixed alkalies and metals, it forms falts, differing in many refpects from thofe that are produced by the ordinary acid. The volatile alkali it decompofes: forming water with the hydrophloge of it, and abforbing the phlogifton, fo as to be itfelf converted into the common marine acid: and finally, difengaging the mephitis, and reftoring it to its aerial form.—By diftilling it in M. *Woulfe's* apparatus, kept perfectly cool by means of ice, M. *Berthollet* has procured part of this acid in a concrete ftate; an obfervation which ferves to confirm the conjecture we have hazarded above, relative to the glacial oil of vitriol. [E]

* The dephlogifticated marine acid and aqua regia, being endowed with one and the fame property, viz. that of diffolving gold, and refembling each other in various refpects befides, we do not hefitate to affert that the active and efficient part of aqua regia is merely dephlogifticated marine acid, as will farther appear from the confideration of the following facts:

Firft, a mixture of the common marine and nitrous acids is known to make aqua regia. The nitrous acid here feems to lofe its property of being nitrous acid, giving out its dephlogifticated air to the marine acid; and having loft its dephlogifticated air, forms phlogifticated nitrous acid, and produces the red colour of the liquor. In cafe the marine and nitrous acids are in an equal proportion, there is a little of the nitrous acid undecompofed.

Secondly, if the nitrous acid be mixed with the marine, in the proportion of one only to four; it will be entirely decompofed; as in this cafe, the marine acid will take up all the dephlogifticated air of the nitrous acid, and thus phlogifticate it entirely, or, as M. *Lavoifier* expreffes himfelf, deprive it of its oxygenous principle. (See M. *Pelletier's* Experiments in the Journal de Phyfique, Tom. 26. p. 303.) After thefe two acids are mixed, an air efcapes, (Ibid. p. 223.) which is a mixture of the dephlogifticated marine acid air and of nitrous air, which decompofing each other, form nitrous and common marine acid.

Dr. *Prieftley* has difcovered a method of procuring a very ftrong aqua regia, by making the marine acid imbibe nitrous vapor, the rationale of which is as follows: the nitrous vapor containing a large portion of dephlogifticated nitrous air, gives the marine acid that bafis, without giving it any water.

Aqua regia is likewife made, though of a much weaker fort, when a certain portion of fal ammoniac or of common falt is put into nitrous acid; for in this cafe, one part of the nitrous acid difengages the marine acid, while the other part combines with the alkali thus freed from its former bonds. [D]

† The precife time of the invention of the three mineral acids abovementioned, cannot be determined. It is certain, however, that they were not known before the twelfth century. There are no veftiges to be met with, either in *Geber*, *Avicenna*, or *Roger Bacon*, of their having known how to prepare this acid. In *Raymond Lully*, on the contrary, we difcover fome traces

The *fluor acid*, which muſt certainly now be acknowledged to be the fourth of the mineral acids, was firſt prepared by M. *Marggraf*, though it ſeems that his attention was more directed to the earth volatilized in the operation, than to the peculiar nature of the acid*. *Scheele* afterwards examined it with greater preciſion as an acid, and deſcribed its properties †. For the preparation of it, pulverized fluor-ſpar and oil of vitriol, are mixed together in equal parts, and diſtilled by a due degree of heat in a glaſs retort, ſome water being previouſly put into the receiver. Inſtead of the vitriolic acid, two parts of the nitrous or marine acid may be employed for the expulſion of it. A ſimilar ſeparation is alſo produced by the phoſphoric acid. In ſome of its properties, viz. in its ſmell and volatility, it reſembles the marine acid; but in its other qualities, it is the reverſe of this acid. In diſtillation it exhibits the peculiar phenomenon of a part of its vapors forming an earthy cruſt upon the water put into the receiver, as ſoon as they touch its ſurface; the greater part of them penetrating into the water, which is thus rendered very acid; and from which a great quantity of earth may be precipitated by means of alkaline ſalts.

M. *Scheele* did not at firſt ſuppoſe the earth which appeared in the operation, to be an earth ſeparated either from the fluor ſpar or from its acid, but imagined that it had ariſen from the combination of its ſpecific acid with the vapors of the water; his opinion however may now poſſibly be altered with reſpect to this ſubject‡. *Boulanger* is of opinion that the fluor acid is the marine acid, along with which ſome earthy ſubſtance has been carried over. *Monnet*, on the other hand, rejects the idea of its partaking of the nature of the marine acid, and affirms with *Prieſtly*, that the acid which comes over is of the vitriolic kind. But *Scheele's* opinion, that it is an acid peculiar to the fluor ſpar, has ſince been evidently confirmed, although he was entirely miſtaken with reſpect to the origin of the earth.

According to my own obſervations, the fluor contains a very peculiar and appropriate acid, which, till it was obſerved by *Marggraf*, was entirely unknown, and which, according to the experiments hitherto made, has been

of his having been acquainted with it; from whence it may be inferred that it was invented towards the end of the 13th or elſe at the beginning of the 14th century, with which alſo *Abraham Eleazar*, who lived at the ſame time, concurs.

* Memoires de l'Acad. de Berlin, Tom. XXIV, for the year 1768.

† Trans. of the R. Swediſh Acad. of Sciences, Vol. 33. alſo *Crell's* Chemiſches Journal, Vol. II. p. 192.

‡ M. *Scheele* acknowledged his miſtake ſome time before his death. [E.]

found

found chiefly to exist in the substance called fluor spar. It is an acid, of which the most distinguishing characteristic consists in this, that it will not only dissolve siliceous earth, but also raises this substance aloft in the form of vapors, and carries them over with it in distillation. It is an acid salt, which, mixed with alkalies, produces particular kinds of neutral salts, and, even in this state, corrodes glass. In short, it is an acid, which by reason that, when prepared in glass vessels, it corrodes the glass to such a degree, as to produce the phenomena beforementioned, cannot be obtained in a pure state in this way*.

From the four mineral acids, concerning which we have been hitherto treating, the following are distinguished by being in a concrete state and of a more fixed nature, the cause of which may probably be, that they consist of a larger proportion of earthy *constituent parts.*

*Sedative salt*, which was first discovered by *Becher*, and afterwards more accurately described by *Homberg*, was at first grossly misunderstood with regard to its origin; as appears by its ancient appellation of *sal volatile vitrioli narcoticum.* For it was supposed to be obtained from vitriol. This mistake was in some degree rectified by the younger *Lemery*, who separated this salt from borax, by means of all the mineral acids. Notwithstanding this, he was still of opinion that it was generated by these acids during the operation. After him, *Geoffroy* indicated a better way of preparing it, principally by means of crystallization. But finally, it was proved by *Baron*, that this salt might be obtained from borax, not only by every species of mineral acid, but also with the assistance of the weak vegetable acids, and consequently that, beyond any farther doubt, it was actually a constituent part of the borax.

This salt is, in fact, a concrete and fixed acid, which in the dry way will expel most of the pure acids, the vitriolic excepted. It may be fused without any addition, when it forms a glass-like substance, which however dissolves

* *J. C. Wiegleb's Chemical Investigation of the fluor acid, relatively to the earth combined with it*; in the *Neueste Entdeckungen*, Vol. I. p. 4, & 15. All that I have advanced in this paper has been since placed beyond all doubt by *C. F. Wenzel's Chemical Investigation of the fluor spar, Dresden* 1783, 8vo: as also by *J. C. F. Meyer's* Experiments in the *Schriften der Berl. Geselsch. naturf. freunde*, Vol. II. and in like manner by M. *Scopoli*, in the *Chemical Annals*, Vol. I. p. 236.

For a very ingenious application of the chief property by which this acid is distinguished, viz. that of corroding glass, the public is indebted to Count *G.* of *Berlin*, who has indicated to artists the means of availing themselves of this quality of the fluor acid, by applying it to the purpose

ſolves again in water, and when this water is drawn off from it by diſtillation, is in part ſublimed along with it. It diſſolves in ſpirit of wine, which it cauſes to burn with a green flame. With alkaline ſalts, agreeably to its acid nature, it forms various neutral ſalts ſomewhat of the nature of borax. On being diſſolved in water, it cryſtallizes in the form of fine ſilver-coloured laminæ, of a light and porous texture. As yet we know nothing with any certainty relative to its compoſition.

At preſent it is ſeparated from borax alone, by the following proceſſes. The firſt and moſt ancient proceſs, by which it is procured from borax by a humid ſublimation, with the addition of colcothar of vitriol or pure vitriolic acid, is now diſuſed on account of its tedioufneſs. In the other proceſs which is in uſe at preſent, it is ſeparated by cryſtallization and the addition of acids. For this purpoſe, the borax is diſſolved in a proper quantity of boiling water, and pure vitriolic acid is gradually mixed with it, till the mixture acquires an acidulous taſte. Any other pure acid may be ſubſtituted for the vitriolic. The lixivium while it is ſtill hot, is immediately ſtrained off, and removed to a cool place. After cryſtallization has taken place, the remaining liquor is evaporated, and again ſet by for farther cryſtallization, and this proceſs is continued till no more ſedative ſalt can be obtained from it. This latter muſt be well waſhed ſeveral times with cold water. In the year 1777, M. *Hofer*, Inſpector of the Grand Duke's Diſpenſary at *Florence*, diſcovered in different waters of the Dukedom of Tuſcany, ſedative ſalt, of which he compoſed a perfect borax by means of mineral alkali. This is the firſt diſcovery of ſedative ſalt exiſting any where in nature, excepting in borax †.

purpoſe of engraving upon glaſs, and eſpecially glaſs plates. This Nobleman's method of engraving letters or figures upon glaſs, is the ſame, mutatis mutandis, as that uſed by ordinary engravers upon copper. A plate of looking-glaſs is to be covered with melted wax, or with maſtich. When this coating is become hard, the figures or letters are to be engraved upon it with a very ſharp-pointed needle, or other pointed tool. After this, a mixture of the fluor acid and oil of vitriol is to be poured upon it. In order to prevent the evaporation of the acid, the whole is to be covered with an inverted china-plate. Two days after, let the glaſs-plate be cleared of its coating; when all the traces of the needle will be found upon it. (Vid. Chemiſche Annalen, 1786. 12 Stuck.

† Meſſrs. *Struve* and *Exchaquet* have lately attempted by a great number of experiments to prove that ſedative ſalt is a compound of phoſphoric acid and ſiliceous earth; but as upon the whole, the proofs of the identity of the ſalts were far from being deciſive, we muſt ſtill continue to conſider borax as a ſalt compoſed of ſedative ſalt and mineral alkali; and the ſedative ſalt as an acid ſui generis.

The

The claims of *arsenic* to the nature of a salt cannot be denied, at the same time. Moreover, it has this quality, that when treated in the fire, with the addition of a sufficient quantity of phlogiston, it fuses and forms a peculiar metal, known by the name of *Regulus of Arsenic*. Thus the nature and properties of a salt as well as of a metal are both united in this substance. When it is in its metallic state, and as it were, replete with phlogiston; it then least manifests its saline nature; but in its calcined state, as it occurs in common *white arsenic*, it is found to be more saline; as it then dissolves in boiling water, though in a small quantity, namely, one sixteenth, and unites with alkaline salts so as to form aneutral salt: it acts likewise in the dry way like a strong acid, and expels other acids from the alkaline salts with which they are united. White arsenic does not exhibit its saline properties so very apparently, because it is still accompanied with a small portion of phlogiston; but when it is entirely freed from this principle, it shews its acido-saline nature in a much greater degree, but at the same time, (which is very remarkable) loses somewhat of its volatility. This scope, according to *Scheele*, the first discoverer of this acid, is attained in the following ways. In the first place, by distilling three parts of dephlogisticated marine acid, over one part of white arsenic, in a retort, by a red heat: or, secondly, by dissolving in a retort, two parts of white arsenic in seven parts of spirit of salt, and then pouring upon this 3½ parts of nitrous acid, and distilling off all the liquor to dryness, and at length urging it with a red heat. In both cases, the arsenic is found concentrated in the residuum, and in a dephlogisticated and acido-saline state. In this state, it has been called the *arsenical acid*. But as this residuum is still arsenic, and that entire and undecomposed, with the privation only of that portion of phlogiston which adhered to it when in the state of white arsenic*, I do not find this appellation at all suitable to its nature or properties; and am of an opinion that the name of *dephlogisticated arsenic* is more applicable to it. As it is found in the residuum, it is in a solid and concrete state; it may however be dissolved in twice its weight of water, and brought into a liquid form. White arsenic, in this operation, loses 20 parts in 100 of its weight; whence it is supposed that 100 parts of white arsenic contain 20 of phlogiston. When dephlogisticated arsenic is sublimed, it re-assumes the nature of white arsenic, and by the addition of phlogiston is again converted into regulus of arsenic. In the mean time, in this dephlogisticated state, it expels, in the dry way, the liquid volatile acids from the alkaline salts.

* It also receives air from the nitrous or dephlogisticated marine acid; and consequently as well in its origin as its properties, is perfectly analogous to other acids. [E]

Another late discovery of *Scheele*, is that of a peculiar acid in molybdæna or black-lead, *(molybdæna membranacea nitens)* which he has called the *molybdænic acid.* After he had five times abstracted the diluted nitrous acid in the quantity of six ounces at each time, from 12 drachms of pulverized molybdæna, there remained at last a powder as white as chalk, which weighed 6½ drachms, was perfectly soluble in twenty times that weight of water, and gave it an acid and almost metallic taste. A similar acid-earth, though less pure, was obtained from molybdæna melted with nitre. In order to prove that a portion of sulphur only had been destroyed, and that molybdæna is composed of sulphur and a peculiar acid, *Scheele* asserts, that from true molybdæna may be re-generated one part of this acid and three of sulphur *.

Finally, *Scheele* has produced an acid of a peculiar kind from *Tungsten*, (the lapis ponderosus *Bergmanni*, ferrum calciforme, terrâ quadam incognitâ intime mixtum, *Cronst.)* which may be distinguished by the name of the *Barylithic* or *Tungstenic acid.* To obtain this, one part of the pulverized-stone is mixed with four of salt of tartar, and fused in an iron crucible. The fused mass being poured out, is then dissolved in ten times its quantity of boiling water, and the solution is decanted off clear from the powder that settles at the bottom. This residuary powder being edulcorated, nitrous acid is added to it till the effervescence ceases to be perceived, by which means a great part of the powder is dissolved. That which still remains undissolved, is now dried and mixed with four times its quantity of salt of tartar, and fused as before; this mass is then dissolved afresh in water, and the remainder in nitrous acid, when a very small quantity of grey powder will remain behind. After this, the alkaline lixivia are precipitated with nitrous acid, and hence is obtained the pure *Barylithic Earth*, or *Earth of Tungsten*, which is of an acido-saline nature. The solutions in nitrous acid being *precipitated by fixed alkali, yield calcareous earth.* Pure Barylithic Earth, or Earth of Tungsten, is also produced in another manner, which is as follows: Upon one part of Tungsten or Barylithicum, reduced to a fine powder, are poured three

* Vid. Swedish Transactions for the year 1778: Also Neueste Entdeck. in der Chemie, Vol. VI. page 176—188.

According to M. *I. C. Ilsemann*, the molybdæna of *Altenberg* contains very little or no sulphur, neither is it volatile in the fire, as was that which was examined by *Scheele*. From the analysis made of it by this experienced Chemist, the molybdæna of *Altenberg* appears to be a peculiar earth combined with a peculiar acid, (which attracts the phlogiston from metals with great force), some vitriolic acid, air, a little phlogiston, and a small quantity of iron. (Chemische Analen, 1787. Vol. I. p. 407.)

 parts

parts of aqua fortis, from which no effervescence will ensue. In consequence of being digested both together, the aqua fortis and the powder acquire a yellow colour. The yellow powder being edulcorated is then digested with caustic spirit of sal ammoniac, and assumes a white colour. The residuum is now elixated again; and once more digested with nitrous acid, and then with caustic spirit of sal ammoniac, which is frequently repeated, till a very small portion only is left undissolved. Here again, the acid solution contains merely calcareous earth; but from the caustic spirit of sal ammoniac, a white earth is precipitated by nitrous acid, which, when edulcorated, consists of pure *Barylithic Earth*, or Earth of Tungsten, which is also considered as the true *concrete Barylithic acid*. It possesses the following properties: viz. If 20 times its quantity of boiling water be poured upon it, the solution will have an acid taste, and tinge the tincture of litmus red. If lime-water be boiled with this acid of solution, regenerated Tungsten will be produced. This acid earth with borax, produces a blue, and with fusible salt of urine, a sea-green glass; submitted to the blow-pipe, this concrete acid becomes first of an orange-colour, then it turns brown, and, in the last place, black; without either smoking or exhibiting any sign of fusion. If this concrete acid is boiled with a little marine or nitrous acid, the powder becomes yellow, and with vitriolic acid, bluish. This acid, dissolved in water, forms with alkaline salts different neutral salts. When saturated with salt of tartar, very small crystals make their appearance. With volatile alkali, it produces an ammonical salt, in figure resembling the points of small needles. In the distillation of this species of sal ammoniac, the volatile alkali comes over in a caustic state, and the acid remains behind, in the form of a yellow powder. This ammonical salt is also decomposed by calcareous nitre, and the acetated terra ponderosa by this acid. With magnesia, this acid forms a neutral salt, which is of difficult solution in water. The solutions of earth of alum and of lime in acids, are not decomposed by this acid. The vitriols of iron, zinc and copper, lunar, mercurial and saturnine nitre, and saturnine muria, (or muriated lead) it precipitates of a *white* colour; but jovial muria, (or muriated tin) *blue*; corrosive sublimate, and the solution of gold, not at all. When this acid solution is mixed with a few drops of marine acid, and passed over polished iron, tin, or zinc, it will acquire a fine blue colour; the same effect takes place when these metals are put into the acid. This acid distinguishes itself from the molybdænic by the following circumstances: first, inasmuch as it is fixed; secondly, as it exhibits less affinity with phlogiston: thirdly,

thirdly, inasmuch as it is not easily dissolved by the nitrous acid, and, on the other hand, acquires a yellow colour in it, remaining all the while in a solid state: fourthly, as terra ponderosa combined with our acid is insoluble in water: fifthly, by the ammoniacal salt spoken of above, inasmuch as genuine Tungsten is regenerated from calcareous nitre*.

By the appellation of *phosphoric* acid, is understood that acid which by its combination with phlogiston forms phosphorus, and, as a clear proof of this, may also be separated from it again. It seems, indeed, to belong to the animal kingdom, whence it is true, we obtain it in the most convenient manner, and in the greatest quantities, for our use: the conclusion, nevertheless, does not directly follow, that it derives its origin from that kingdom. The experiments made by *Albin*, *Hoffmann* and *Marggraf*, (mentioned at the article phosphorus) and shewing that phosphorus may be obtained from vegetable substances, have long ago weakened the force of this hitherto adopted position. Besides this, M. *Meyer* has very lately discovered this acid in the green resinous constituent parts of the leaves of plants †. But if, without having recourse to *Sage's* authority, to shew that the phosphoric acid may be met with in abundance in the mineral kingdom, which yet he has never proved; we consider more recent and more authentic observations, e. g. that phosphoric acid has been separated from a calciform lead-ore, by *Gahn* ‡; from talc, by *Scopoli* §; from siderum, by *Meyer* and *Klaproth* ¶; and that it has lately been found in the *Tschopau* green lead-spar: it will appear more than probable that this acid ought to be referred to the mineral kingdom. From this it probably passes into vegetables, and thence, (being taken in the way of food) into the bodies of animals. Its fixity too is a strong proof in favour of this position. *Homberg* separated it first in 1712, from phosphorus itself, by suffering it to undergo a spontaneous combustion, in the open air. *Marggraf* afterwards acquired a farther knowledge of it by repeated decompositions of phosphorus; his method of operating, was to suffer this latter substance to burn in a china

* *Kongl. Vet. Acad. Nya Handl.* T. II. for 1777, p. 89: also in *Neueste Entd. in der Chemie*, Vol. X. p. 209. *Chem. Ann.* Vol. II. p. 201.—205. The manner in which the Tungstenic acid may be obtained from Wolfram, may be seen in my *Chemical Investigation* of this mineral, in the *Chemical Annals*. [A]

† Chem. Annal. Vol. I. p. 521. ‡ Bergman on the blow-pipe, §. 25. § Chem. Annal. Vol. I. pag. 237. ¶ Ibid. pag. 195 & 390.

 saucer,

ſaucer, under a glaſs bell mounted, with the capital of an alembic, when a ſmall part ariſes in the form of flowers, which however ſoon deliqueſces, in conſequence of the humidity of the air. The reſiduum has the appearance of a light porous earth, weighs more than the phoſphorus that has been employed, and on being elixated with water, yields the acid. This way of obtaining it, is however attended with great expence, and, conſequently, the other method of *Marggraf* is preferable, by which the eſſential ſalt of urine, prepared according to his preſcription, is freed of all its volatile alkali, by a fire encreaſed to ſuch a pitch, as to make the retort containing the ingredients, red-hot. From the reſiduum being fuſed in a crucible on a briſk fire, the ſame acid is obtained by elixation with water. It is fixed of itſelf, and fuſes to a glaſs-like body, which however is ſoluble again in water. It is a diſcovery made by *Scheele*, in theſe later times only, that this acid is alſo found in the ſolid parts of animals, and that phoſphorus may be made of it, facts which have been ſince made more public by Dr. *Gahn*, of *Stockholm*, in the year 1769. For this purpoſe, hartſhorn burned to whiteneſs, or any other bones, are perfectly diſſolved in a ſufficient quantity of diluted marine acid*; and the filtered ſolution diluted with three times its quantity of water, when vitriolic acid is dropped into it till no farther precipitation enſues. The whole is then put upon a filter, and freſh water poured on the earth which remains behind, till there is no more acid perceptible to the taſte. This earth conſiſts of ſelenite; but the filtered liquor conſiſts of the acid that has been employed for the ſolution, and of the acid of phoſphorus. This liquid may be evaporated to one fourth in a large unglazed earthen veſſel, whence it is to be poured into a glaſs retort, when all the water is firſt to be expelled apart, and then the whole of the marine acid, which may afterwards be employed again in ſimilar experiments. The diſtillation muſt not be continued to abſolutely dryneſs, but merely to the conſiſtence of oil. What remains in the retort on this occaſion, is to be diluted with water, and all the inſipid earth, which is nothing elſe than a ſelenite that was diſſolved at the beginning of the operation, but concreted again on the evaporation of the liquor, is to be ſeparated by filtration. Dr. *Gahn* conſiders this liquor as pure phoſphoric acid, but it is not ſuch as yet, and muſt be firſt made ſo. There is ſtill enveloped in it a large portion of calcareous earth, which cannot be entirely ſeparated from it by the vitriolic acid. If it be required to ſeparate this, the ſureſt method

* The nitrous acid is not adviſable here, on account of a terrible accident having happened from the uſe of it, vid. Neueſte Entdeckungen in der Chemie, Vol. X. pag. 134.

will

will be to precipitate the acid with a weak and mild ſpirit of ſal ammoniac, to evaporate the filtered ſaline liquor to dryneſs, and putting it again into a retort, to expel the volatile alkali from it*. The moſt profitable method of obtaining this acid from bones, according to *Niclas's* recipe, is deſcribed in the phyſical part of this work †. If it is to be uſed as a pure acid, it muſt to be evaporated to dryneſs, and diſſolved again in a little diſtilled water. The moſt remarkable properties of this acid, are the following: it exhibits leſs affinity with the calcareous earth, viâ humidâ, than the vitriolic acid; though it cannot be ſeparated from the ultimate reſiduum of the calcareous earth, by this acid; while, on the other hand, it expels this and all other liquid mineral acids from alkaline ſalts and earths in the dry way. It precipitates iron from its ſolution in the vitriolic acid, of a perfectly white colour. The inſpiſſated concrete acid exhibits alſo a remarkable degree of gravity, and that prepared according to *Gahn's* receipt, from which the ultimate occult portion of calcareous earth has not been ſeparated, may be melted in a crucible over a pretty briſk fire, without any other addition, to a perfectly colourleſs, and tranſparent glaſs; from which, according to Profeſſor *Crell*, by the addition of a little charcoal-duſt, phoſphorus may be extracted, which will be found as good as that which is made from the acid before it was fuſed ‡.

To

* Chemical Inveſtigation of the acid extracted from bones, in the Neueſte Entdeck. in der Chemie. Vol. II.

† M. *Hofmann*, of *Leer*, in *Eaſt Frieſland*, aſſerts that this acid is to be obtained in M. *Niclas's* method, from fiſh-bones, in a much greater quantity than from any other ſubſtance. *Chem. Annals*. Vol. II. 1787. [E]

‡ Though both M. *Homberg* and M. *Marggraf* have decompoſed phoſphorus, we are indebted to M. *Lavoiſier* for a more accurate decompoſition of this very inflammable ſubſtance, who, at the ſame time, is the firſt Philoſopher that has pointed out its component principles. This gentleman *gradually* introduced a quantity of phoſphorus into nitrous acid, the ſpecific gravity of which was 1,299, and which was heated to 133°, and obſerved a large quantity of nitrous air to be produced, and the phoſphorus almoſt wholly converted into phoſphoric acid, and increaſed in weight above the double. Hence he concluded that the phoſphorus united itſelf to the oxygenous principle, which he ſtates to be in the acid to the amount of 2,265 of its own weight. (Memoires de Acad. des Sciences, 1780, p. 350.) But M. *de Morveau* made an experiment that evidently proved the dephlogiſtication of the ſubſtance during its acidification, and that pure air becomes fixed air before it unites to it. Having left a piece of phoſphorus in a large glaſs veſſel ſtopped for three or four days, expoſed to a temperature of 70 or 72, and afterwards opened it in lime-water, the lime-water entered and became turbid, and being filtered, left a precipitate which

effervеſcence

To this place may also be referred the acid salt described by *Homberg*, which is generated by mixing two ounces and a half of luna cornea with an ounce and a half of tin calcined alone and without addition, by means of fire, and exposing this mixture to a naked fire in a coated retort, of which two thirds ought to be left empty; when a brownish matter of the weight of 1½ ounce will adhere to the neck of the retort. This matter is tin combined with marine acid; but the residuum is silver deprived of the marine acid; which now may be fused together into one mass without any loss. The sublimate being pulverized and well dryed, is equably distributed into two phials, and sublimed according to art, for the sake of separating from it the tin which at first rises with it. If this sublimation be repeated two or three times more, a volatile acid, very white and transparent salt is at length obtained. The residuum of these sublimations is always calx of tin*.

effervesced with the nitrous acid, and consequently the precipitation did not arise from the union of the lime with the phosphoric acid. (Encyclopedie de Chemie par M. *de Morveau*, Tom. I. *Paris*, 1786, p. 220.) The basis of the phosphoric acid, as M. *de Morveau* justly remarks, is the only one that can be procured free, both from phlogiston and the acidifying principle: it is what is called (though improperly, since it is insoluble in water) the glacial phosphoric acid.

Mr. *Kirwan*, from whom this note is taken, concludes as well from the experiments of M. *Lavoisier* as from those of M. *de Morveau*, that fixed air is the acidifying principle of the phosphoric acid. The experiment cited at the beginning of this Note, he explains thus: "As I have already shewn that nitrous air contains a large quantity of phlogiston, and that it does not pre-exist in the nitrous acid, I must consider that produced on this occasion as a proof that phosphorus contains phlogiston, and that it took fixed air from the nitrous acid; but the surplus weight which the phosphoric substance possessed after the operation, cannot be entirely derived from the nitrous acid, inasmuch as common air must have been admitted during the gradual introduction of the phosphorus." (Vid. *Kirwan's* Essay on Phlogiston and the Constitution of Acids, p. 86. *London*, 1887.) [D]

What M. *de Morveau* calls the basis of the phosphoric acid, seems to be nothing else than phosphorus partly decomposed by the air, i. e. united with a less quantity of air than is sufficient to acidify it; and consequently still retaining a considerable portion of phlogiston. It is white, and bears great analogy to white arsenic. [E]

* This artificial concrete acid salt has probably still some earth of tin for its basis. Since this, no one seems to have thought it worth while to attempt any farther investigation of the matter. [A]

Messrs. *Hassenfratz* and *Pelletier*, if they have not been deceived by some of those illusive circumstances which frequently mislead the most experienced Chemists, have lately procured acids, not only from tin, but likewise from iron, bismuth and antimony. Vid. *Journ. de Physique*. [E]

 Exclusively

Excluſively of the mineral acids hitherto mentioned, there are two ſorts more, which, beſides earthy, contain alſo oleaginous parts. Both are moreover of ſuch a nature, that their mineral origin might be diſputed. Under this deſcription I comprehend the *acid ſalts of amber*, and of *ambergriſe*.

*Salt of amber* is a real conſtituent part of the amber, from which as yet it can only be obtained by way of dry diſtillation. It ſeems to have been firſt diſcovered by *Agricola*. For this purpoſe, the amber may be diſtilled in a retort half filled with it, either by itſelf, and without any other addition whatever, or elſe mixed with an equal quantity of ſand. In this operation, if the fire be but gradually increaſed, and the diſtillation not overhurried, the ſalt will appear juſt at that period, when a perfectly limpid oil is paſſing over. It commonly happens however, that the ſalt is diſſolved by the phlegm, and together with that, is ſo blended with the great quantity of oil that is at this time paſſing over, that it cannot be eaſily ſeparated from it, and that the greateſt part of the acid-phlegm remains enveloped and concealed in the oil, and is loſt. In order to remove this inconvenience, it is adviſable before the diſtillation is begun, to pour into the receiver half as much water as there is amber to be diſtilled. By this means the ſmall quantity of the phlegm of the amber is augmented, and the greateſt part of the volatile ſalt that comes over is diſſolved, ſo that the ſeparation of it from the oil may be conveniently effected. After the ſeparated phlegm has ſtood to ſettle for ſeveral days, it may be filtered through double blotting-paper, and the ſalt in conſequence of a gentle evaporation of the liquor, may be ſeparated by cryſtallization. It likewiſe ſometimes happens, that in the belly of the receiver, immediately under the aperture of the neck of the retort, there appears a ſolid lump, which at firſt ſight might be taken for amber carried over the retort in diſtillation, or for a clot of extremely thick oil. But frequently when it is examined and broken to pieces, it is found to be nothing elſe than ſalt of amber mixed with a thick oil. One pound of amber yields nearly half an ounce of ſalt. The finer ſorts yield more than the coarſe*.

* Four pounds of amber properly diſtilled, will yield nine drachms of a fine white ſolid ſalt, which does not ſtand in need of any purification; and the acid liquor that comes over in the diſtillation, and weighs about ten ounces, will yield, with a very ſlow evaporation, about two drachms of this ſame ſalt: but, as much of it is volatilized and diſſipated during the evaporation of the liquid, it is adviſable where the liquor c. c. ſuccinatus is wanted, to ſaturate this liquid with ſalt of hartſhorn. (*Dollfuſs Pharmaceutiſch-Chemiſche Erfahrungen.*)

The purification of this ſalt from the oily particles adhering to it, may be performed in different ways. It is beſt however previouſly during the diſtillation, to endeavour by changing of the receiver, to prevent it from being greatly overcharged with the empyreumatic oil. If this precaution has been neglected, the ſalt is impure, and muſt be diſſolved in from ſix to eight times its quantity of hot water, then filtered and cryſtallized afreſh. Marine acid may alſo be poured upon it, which is to be drawn off again from it, and laſtly, the ſalt ſublimed. In like manner it may be mixed with an equal weight of common ſalt, or of good clay, and then ſeparated from them again by ſublimation. In all theſe caſes, the ſalt will be obtained free from the greateſt part of the adhering oil, and of a fine white colour.

The form of the cryſtals is that of triangular priſms, obliquely truncated at each end. For the ſolution of this ſalt, about three times its quantity of boiling water are requiſite. Spirit of wine aſſiſted by heat, diſſolves but a ſmall quantity of it. That this ſalt is of an acid nature, is evident, by its effervеſcing, when mixed as well with all the mild alkaline ſalts, as abſorbent earths, and by its generating with theſe bodies neutral ſalts of a peculiar kind, which we ſhall deſcribe in another part of this work. With regard to the nature of the acid, the following are its moſt remarkable properties: Firſt, oil of vitriol does not expel any white vapors from it: ſecondly, the neutral ſalt produced from this acid and the vegetable alkali, is of eaſy ſolution in water, and at the ſame time fixed in the fire. It does not convert aqua fortis into aqua regis. Neither does it precipitate ſilver from its ſolution in aqua fortis; although it has this effect upon lead diſſolved in vinegar, without converting it however into plumbum corneum. Thirdly, mixed with nitre, it will in a red heat, cauſe a detonation, in which the mere alkali only of the former ſubſtance is left behind. Fourthly, fuſed together with alkali and charcoal powder, it does not form liver of ſulphur. Fifthly, when this ſalt is mixed with nitrous acid, no aqua regia is produced. Sixthly, it expels the marine acid from ſal ammoniac. Seventhly, it diſſolves chalk, and forms with it a cryſtallized ſalt, from which the chalk is to be precipitated by the vitriolic acid only. Eighthly, a ſolution of ſalt of amber, moreover, precipitates chalk from a vegetable acid; though it will not precipitate this ſubſtance when diſſolved in a mineral acid. Ninthly, the ſalt of amber being mixed with chalk, cannot be ſeparated from it again, either by the ſtrongeſt acetous or by the marine acid; but it may be expelled by acid of vitriol, with the aſſiſtance of fire. Tenthly, the ſolution of this ſalt in water, diſſolves copper, with a graſs

a grafs-green colour. Eleventhly, the folution of iron in this acid, produces a yellow colour. Twelfthly, it diffolves tin likewife, but lets it fall again in the form of a white calx. Thirteenthly, it does not act at all upon lead. Fourteenthly, it eafily diffolves zinc. Fifteenthly: But not fo eafily bifmuth. Sixteenthly: the folutions of filver and mercury in the nitrous acid are not precipitated by it. Seventeenthly, nor yet lead, diffolved in nitrous or marine acid. Eighteenthly: But lead combined with acetous acid, is rapidly precipitated by it, though without being converted into plumbum corneum. Now when all thefe properties are duly confidered and compared together, no other judgment can be formed of the nature of falt of amber, than that it is an acid falt of a peculiar kind, and cannot be referred to any of the known mineral, vegetable, or animal acids.

When the acid liquor, contained in the falt of amber, is intirely freed from all its oil, which is carried off by evaporation, a particular fmell is perceived, which, together with the dark-brown colour, is alfo retained in the falt, and which is very different from the fpecific odour of oil of amber. It is very fimilar to the fmell of empyreumatic vinegar of wood, or to that of wood-foot. From this circumftance one would be apt to conclude that amber has fome relation to the vegetable kingdom, or even that it derives its origin from that kingdom. The fame dirty fuliginous matter is alfo the caufe that the falt of amber alone, and without any addition, is purified with fo much difficulty; becaufe, after the evaporation, the greateft part of it is always diffolved afrefh, together with the falt.

The acid of *ambra*, or *ambergrife*, is obtained like the falt of amber, in a concrete form, by diftillation with a naked fire. Little more can be faid here of this falt than that it exifts: for as yet, fufficient enquiry has not been made into its properties, on account of its high price. And how many Chemifts are there, who, like me, have never once feen it? Dr. *Kriele*, Phyfician at *Batavia* and *Great Java* in the Eaft Indies, whofe chemical analyfis of ambergrife is to be found in the *New Hamburgh Magazine*, Vol. I. p. 145, did not once fee it appear in his operations. He is therefore of opinion that this acid is contained in amber, in a very fmall quantity only, and that no obfervation can be made upon it, unlefs feveral pounds at leaft of amber be employed for the purpofe.

The *vegetable* acids likewife differ from each other in various ways. Some of them are fufficiently *manifeft* in the plants which produce them; while others, on the contrary, are more enveloped and *occult*. Some of them appear in a *liquid*, others in a *folid* and *concrete* ftate. They are chiefly diftinguifhed from the preceding acids by their deftructibility in fire; and though they may be brought to compofe various kinds of neutral falts, by being combined with alkaline falts, and

earths of every ſort, yet they are forced univerſally to give place to the mineral acids. According to their peculiar nature, and the combinations they have entered into, they muſt be ſeparated by different intermediating ſubſtances, by fermentation, or by fire.

The *manifeſt* vegetable acids, which are inſtantly diſcoverable by the taſte, are commonly *liquid*, and loaded with viſcid particles; on which account they are not poſſeſſed of nearly that degree of acrimony and ſharpneſs, which is obſerved in the mineral acids. Hence alſo it is that they are inclined to putrefaction, and acquire an empyreumatic ſmell when they are expelled by a naked fire. For want of a more preciſe inveſtigation, we are not as yet ſufficiently acquainted with the greateſt part of them, as to their peculiar chemical properties. Among thoſe which are beſt known, are the acids of *lemons*, of *berberries*, and of *currants*.—The acid of *lemons* is obtained by mere preſſure of the pulpy part of this fruit; which is filtered after a previous and ſpontaneous clarification, and kept in a cool place in glaſs bottles, covered with a fine and perfectly taſteleſs expreſſed oil. In order to obtain the *pure acid of lemons*, the lemon juice is ſaturated with chalk, while it is boiling over the fire. Upon this, the precipitated earthy ſediment is elutriated, covered with water, and mixed with as much oil of vitriol, as there has been chalk uſed for the ſaturation. Finally, the ſelenite generated by this means is ſeparated, and the reſiduary liquor cryſtallized. *Chemical Annals, for the year* 1784, Vol. II, pag. 3.—The very ſame proceſs may ſerve for the acid juice of *berberries*, which may be uſed in all caſes, as acid of lemons; and of which, I will mention here one of the uſes only, viz. for making punch: *Berberry-punch*, of a beautiful red colour, may be made in the following manner: Take ſix parts of tea, two parts of arack, two of ſugar, and one of the juice of berberries. *Simon Pauli* mentions likewiſe a method of obtaining a concrete *acid ſalt* from this juice: With 24 ounces of it let there be mixed two ounces of the juice of lemons; let the veſſel be kept ſeveral days in a warm place, when the liquor muſt be filtered, and after being ſufficiently evaporated, ſet by in a cellar, where it muſt remain undiſturbed, to cryſtallize. Upon which the evaporation and cryſtallization are to be repeated till all the ſalt is ſeparated from it.—The acid of *currants* is in like manner of conſiderable importance; we know however nothing more of its nature, than that it is procured by previouſly combining the juice with fixed vegetable alkali, and then expelling it in the form of acid vapors, by the addition of vitriolic acid. It is alſo obtained by preſſure, and kept in the ſame manner as other acids of this kind. It is to be ſuppoſed that many other acids of this ſort are to be met with in Nature.

 The

The different acids inherent in fruits, are of a very compound nature. For the lateſt accurate inveſtigation of a great number of them we muſt again acknowledge ourſelves indebted to M. *Scheele* *. The reſult of it is, that in all kinds of fruits there is either an acid, which is entirely the ſame with the pure acid of lemons, or, elſe another ſpecific acid, which he calls the acid of *apple* †, becauſe it is found in the juices of all ſorts of ſour apples. In order to ſeparate this in its utmoſt purity, M. *Scheele* ſaturated the juice of apples with fixed alkali; and poured vinegar of lead upon it, till nothing more was precipitated. After this, the precipitate being firſt edulcorated, he poured diluted acid of vitriol upon it, till the mixture exhibited a pure acid taſte without any ſweetneſs; after this, the liquor was ſeparated by filtration. The depurated acid of lemons and apples are diſcriminated from each other by the following properties. 1. The acid of *lemons* ſhoots into beautiful cryſtals. 2. It does not produce the ſacharine acid by means of nitrous acid. 3. it forms with calcareous earth a ſubſtance almoſt inſoluble in boiling water. 4. it produces no alteration in the ſolutions of mercury, lead and ſilver in nitrous acid, nor in a diluted ſolution of gold. 5. it has a greater affinity with calcareous earth than the acid of apples has. For if lime diſſolved in acid of apples, be boiled one minute with ammoniacal citrocrate, a calcareous citrocrate will fall to the bottom. The acid of *apples*, 1. cannot be made to cryſtallize, and is always deliqueſcent. 2. with the aſſiſtance of nitrous acid it generates acid of ſugar. 3. lime combined with acid of apples is more ſoluble in water. 4. it precipitates the abovementioned ſolutions of metals. 5. it forms with all the alkaline ſalts, deliqueſcent neutral ſalts. 6. on being perfectly ſaturated with lime, it forms ſmall ſhapeleſs cryſtals, which require a great quantity of boiling water for their ſolution: if however the acid be a little predominant, they are eaſily diſſolved in lime-water. 7. it has the ſame effect with reſpect to the terra ponderoſa. 8. it forms a deliqueſcent neutral ſalt with magneſia alba. 9. with earth of alum it produces a neutral ſalt, which is of very difficult ſolution in water. 10. with zinc, it forms beautiful cryſtals, but with iron, a brown ſolution,

* Chem. Ann. for the year 1785, Vol. II. p. 291—303.

† This acid may likewiſe be properly denominated the *melic* acid. According to *Scheele*, it is found alone, or nearly ſo, in a variety of fruits beſides the apple, e. g. in berberries, elderberries, ſloes, plums, and the fruit of the mountain-aſh: and, (mixed with about an equal quantity of citreous acid) in gooſeberries, white, red and black currants, whortleberries, the fruit of the white beam-tree, cherries, ſtrawberries, raſpberries, and cloudberries: but unripe grapes and tamarinds contain no other than the citreous acid. The melic acid differs very little from the galactic. [E]

which will not cryſtallize. Upon the reſt of the metals it is not known to exhibit any remarkable effects.

Of the *occult* vegetable acids, ſome are produced by fermentation, others by fire, others by the active ſubſtances uſually employed by the art. Of the former kind, which are produced by fermentation, I ſhall here only mention *vinegar* as an inſtance; the farther treating of which is reſerved till we come to the diviſion of Zymotechny. This, like all ſimilar fermented acids, is, it is true, with regard to its chief compoſition, not much different from the abovementioned acids. Yet, ſtill it differs from them in this reſpect, that it has been more cleared of the groſs terreo-mucilaginous compound, which is univerſally found in combination with the others. And for this very reaſon it is that the proper acid in the vinegar is in a freer ſtate, ſo that it is capable of riſing in diſtillation, which, for the abovementioned reaſon, it is impoſſible for the other acids to do. Nevertheleſs, the vinegar—and one ſpecies of it more than another—ſtill retains ſome oily and mucilaginous parts, which adhere pretty firmly to it, and will not quit it entirely, even in diſtillation. This is the reaſon that vinegar, as well in the preparation, as the keeping of it, is ſo liable to putrefaction; unleſs ſufficient care has been taken to ſeparate the mucilaginous parts from it. It is likewiſe owing to this circumſtance that the acetous acid ſo eaſily becomes empyreumatic. It is alſo, like the acids of the preceding diviſion, eaſily deſtroyed by fire. Diſtillation is the only way in which the pure acid of vinegar can be obtained free from all other admixtures. In ſmall, it may be performed by means of a glaſs retort in a ſand-bath; and in a large quantity with the ſame ſafety by a copper cucurbit with a pewter head and worm. Of its aqueous part merely, vinegar may be freed by froſt, in which operation however, no ſeparation of its oily and mucilaginous parts takes place, except in the caſe when diſtilled vinegar is ſet out to freeze thoroughly, *ſecundum artem.* This method of concentration conſequently may be taken with weak vinegar in particular. The great abundance of the aqueous part is a perpetual obſtacle to the acid's being concentrated to the utmoſt, merely by rectification. For this reaſon its acid ought to be united with ſome other body, which has a ſtrong attraction for it, in order that the aqueous part only may be evaporated by heat. In former times, copper or lead was uſed for this purpoſe. The ſubſtances were diſſolved in vinegar, the ſolution was evaporated to dryneſs, and the acid thus concentrated, expelled by fire; but very little acid was obtained by this method, as the greateſt part of it was deſtroyed by the violence of the fire. The reſult is juſt the ſame when it is combined with fixed alkaline ſalts by an unſkillful Chemiſt, who imagines he is able to expel a ſtrong acid by itſelf

 and

and without addition from this compound. In this caſe however, nothing but an empyreumatic liquor, and no acid, is obtained.

The *ſtrongeſt ſmoking acid of vinegar* can be obtained by means of the vitriolic acid only*, by pouring upon two parts of copper or lead, which have been diſſolved in diſtilled vinegar, and evaporated to dryneſs, one part of concentrated acid of vitriol, and expelling the volatile acid from this mixture, by a gentle fire. It is obtained in a ſtill more convenient more advantageous and better way, as follows: Fixed alkali is ſaturated with diſtilled vinegar purified and evaporated to dryneſs: for this purpoſe, either the vegetable or mineral alkali may be employed. Then, upon 16 ounces of this dry ſalt, are poured in a retort eight ounces of concentrated acid of vitriol by little and little, and all the acid is drawn over by a gentle fire; by which means are obtained nearly eight ounces of the ſtrongeſt and moſt volatile ſpirit of vinegar, which in point of purity and ſtrength, yields but little to the mineral acids. As vinegar is ſuperior in point of acidity, purity and volatility, to the preceding crude and raw acid juices; in like manner diſtilled vinegar is ſuperior in theſe reſpects to crude vinegar, and the concentrated vinegar here deſcribed, is ſuperior to the diſtilled. The whole difference therefore conſiſts in their different degrees of ſeparation and purification from extraneous parts. It remains however to be examined, in how far theſe vegetable acids, which may be developed by fermentation from the various bodies appertaining to this kingdom, differ from thoſe which may be obtained from them by another method†.

When the occult vegetable acids are to be produced by the action of fire, they will always become empyreumatic on account of their oleaginous parts being at the ſame time inevitably decompoſed and deſtroyed: but after they are deprived of theſe, they exhibit a great reſemblance to vinegar. Of this kind is the *vinegar of wood*, which in the ſmall, may be procured by a dry diſtillation of wood in an iron retort; but in the great, may, agreeably to *Glauber's* advice, be obtained from the fumes of any burning wood. One of theſe empyreumatic acids, having

* It may likewiſe be procured by means of the aerated muriatic acid. [ E ]

† Mr. *Dollfuſs* (*Erfahrungen*, &c.) recommends the following mode of preparing the concentrated acetous acid, as the beſt and cheapeſt. Let 12 ounces of ſugar of lead be diſtilled with half this quantity of vitriolic acid; when ſeven ounces will be obtained of an excellent concentrated vinegar.—It muſt be obſerved, that vinegar thus diſtilled from the calces of metals, conſtitutes what is called the aerated, or dephlogiſticated acetous acid: the metallic calx furniſhing the pure air, and in return, attracting the phlogiſton of the vinegar, by which means the vitriolic acid alſo, which ſerved to ſeparate the acid from the calx, becomes ſulphureous. [ E ]

under-

undergone a previous rectification, may, like the diſtilled vinegar, be concentrated with a fixed alkali: and after the evaporation of its phlegm by means of vitriolic acid, expelled again in a concentrated ſtate.

To this head alſo belong certain *concrete* vegetable acids, which are developed partly by fire, and partly by other means. To this Claſs however, tartar, ſalt of ſorrel, ſalt of wood-ſorrel, and other ſimilar ſalts, are not referred; becauſe they are real neutral ſalts, in which the acid is merely predominant, of which we ſhall treat more amply in the proper place. But theſe acids which are meant here, reſemble the dry mineral acids in this reſpect, that they owe their ſolid and dry ſtate to earthy or oleaginous particles, which are very intimately united with them.

Among them is reckoned the acid of *ſugar**, of which M. *Scheele* is the diſcoverer; though the preparation of it was ſome time afterwards made public by Profeſſor *Bergman*. The preparation conſiſts in the following points. One ounce of fine white ſugar is put into a retort with ſix ounces of moderately ſtrong nitrous acid, which is alſo known by the name of *double aqua fortis*. As ſoon as the retort begins to grow hot in the ſand, vapors of a deep red colour ariſe from it, which conſiſt of nitrous air. When theſe are come over, the diſtillation is ſuffered to proceed ſlowly, till half the liquor be drawn off. When the retort is ſo far cooled, that it may be removed from the ſand without danger, the liquor contained in it, is poured into a glaſs veſſel, in which it is left till the next day, when ſlender priſmatic cryſtals are found to adhere to its ſides. The ſuperincumbent liquor is decanted off clear, and poured back into the retort with three ounces of the abovementioned nitrous acid, when the liquor is drawn off again by diſtillation to the ſame ſmall remainder as before. In this again a portion of ſalt will cryſtallize, from which the liquor is decanted off clear. The whole of the ſalt obtained is then once more diſſolved in diſtilled water, and by this means is again ſeparated from it by a ſecond cryſtallization from the nitrous acid adhering to it. By this operation the nitrous acid deſtroys the phlogiſtic part of the ſugar, and thus liberates the ſaccharine acid, which previouſly to this, was in union with the phlogiſton, and cauſed the ſweet taſte of the ſugar. Beſides the properties this acid poſſeſſes in common with other acids, it is diſtinguiſhed chiefly by the following: 1. ſaturated with common alkali it forms a ſalt, which will not eaſily cryſtallize, unleſs the acid predominates: 2. in the humid way it has a greater affinity to calcareous

* This having been ſince diſcovered to exiſt ready formed in the *Oxalis*, or wood-ſorrel, is with great propriety, by the French academicians, denominated the *oxaline* acid. [E]

earth

earth than any other acid, for which reaſon it alſo ſeparates this earth from its combination with all other acids, and forms with it an earthy ſalt, extremely difficult of ſolution: 3. from the union of it with foſſil alkali ariſes a neutral ſalt, of difficult ſolution: 4. by a moderate fire the acid of ſugar is fuſed; but by a ſtrong fire it becomes brown, throws out a ſmall quantity of water, and a white ſaline cruſt is ſublimed; a greater part of the acid is burned, and a grey or brown earth remains, which amounts to nearly $\frac{1}{30}$ part of the whole acid, and has an empyreumatic ſmell. The affinity it has with other bodies, may be ſeen in *Bergman's* Treatiſe *De Acido Sacchari*. That this acid is exactly the ſame with the *acid of tartar*, which is ſeparated from it in a ſmall quantity by dry diſtillation, *Scheele* has lately evidently proved, by compoſing the ſalt of wood-ſorrel of the acid of ſugar and fixed alkali *. The ſame acid may alſo be obtained from gum arabic and honey, by treating one part of theſe ſubſtances with nine parts of nitrous acid in the manner abovementioned. According to *Bergman*, an acid ſalt ſimilar to theſe is alſo produced by treating eight parts of alcohol with 24 parts of ſtrong nitrous acid †. It alſo, according to *Hermbſtadt*, forms the baſis of the acid we ſhall next ſpeak of, viz. the *Tartareous* ‡. *Scheele* obtained the ſame acid from olive oil §.

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* Chem. Ann. Vol. III, pag. 112.

† Of the ſame kind probably was *Henkel's acid ſalt*, which in his *Kleine mineral and Chem. Schriften*, he deſcribes in the following manner:—" In order to obtain a concrete and acid volatile ſalt, digeſt one part of the beſt aqua fortis with two of ſpirit of tartar, for ſeveral days, and towards the laſt increaſe the fire." The ſame phenomenon was known to *Lehmann*, who deſcribes it thus: " Take two ounces of the ſtrongeſt alcohol; add to it, with the neceſſary precautions, the ſame quantity of ſmoking ſpirit of nitre; let it ſtand well corked up for ſeveral days in the cold. After this, expel it from a glaſs retort at firſt with a gentle fire: thus you will in the firſt place obtain a nitrous naphtha, after which follows an acid ſpirit. Let the fire be increaſed now to the higheſt degree, and a fine white ſalt will be ſublimed, in the form of long needles, which exhibits itſelf in every particular as a volatile acid ſalt." The ſalt alſo deſcribed by Dr. *Weſtendorf*, ſeems to have reſembled this. This gentleman having diſſolved two drachms of red calx of mercury in one ounce of concentrated vinegar, and having abſtracted this ſolution to dryneſs, and expelled it by a ſtrong fire from a retort; a little acid of vinegar diſtilled over firſt, which at the ſame time contained a ſmall portion of mercury: but after this ſome very light glittering flowers, like the flowers of Benzoe, appeared in the neck of the retort.

‡ See his Chemical Eſſay on the Nature of the Acid of Sugar in the *Neueſte Entdeck. in der Chemie*, Vol. IX. pag. 6—29.

§ Chem. Journal, Vol. IV. pag, 190. Chem. Ann. Vol. I. pag. 99: alſo page. 229.

" In explaining (ſays Mr. *Kirwan*, in his Eſſay on Phlogiſton) many of the phenomena of the mineral acids, the antiphlogiſtic theory appears to great advantage from its ſeeming ſimplicity; but

The acid of *Tartar* is the ſecond of this kind. This is alſo one of *Scheele's* diſcoveries, and is prepared in the following manner: Thirty-two ounces of pulverized

but in explaining thoſe of the analyſis and production of the vegetable acids, this advantage is entirely loſt, and its inſufficiency becomes very apparent." In order to give a greater degree of evidence to this aſſertion, it may not be improper to lay before the Reader an abſtract of M. *Lavoiſier's* Experiment, taken from Mr. *Kirwan's* Treatiſe. " M. *Lavoiſier* diſtilled 236,25 grains of ſugar with 945 grains of nitrous acid, the ſpecific gravity of which was 1,316, and which was diluted with 945 grains of water, in an apparatus for receiving airs, and an intermediate bottle for receiving the liquor that might paſs over during the diſtillation. The total amount of the materials therefore was 2126,25 grains, and when the operation was over, the amount was

| | | |
|---|---|---|
| Nitrous air 22,71 cubic inches, | = 85 grains, | which contain 15 of phlogiſton and |
| Fixed air 108,81 - - - | = 60,6 —— | 6,7 of nitrous baſis. |
| Inflammable air 30,22 - - - | = 1 —— | |
| Liquor and Salt in the Retort. - - - - | 1316 | |
| Weight gained by the intermediate Bottle. - - - - | 595 | |
| Total - - - - - - | 2051,6 | |
| Original weight - - - - - | 2126,25 gr | |
| Deduct - - - - - - | 2051, 6 | |
| Loſs - - - - - - - | 74,65 | |

This loſs, continues Mr. *Kirwan*, is ſo conſiderable, that it were ſuperfluous to enter into an account of the quantity of nitrous acid decompoſed, and ſo much the more, as the decompoſition of the nitrous acid is not conteſted. But he takes for granted what cannot be allowed, that the nitrous air pre-exiſted in the nitrous acid, and even that this nitrous acid contained an equal bulk of nitrous and pure air, which Mr. *Kirwan* thinks, in a former Section of this Treatiſe, viz. that on Nitrous acid, he has ſhewn to be impoſſible."

" M. *Lavoiſier*, however, infers from this experiment, that ſugar is a ſort of charcoal which, uniting with the oxygenous principle of the nitrous acid, decompoſes that acid, ſets looſe the nitrous air, and forms the Saccharine acid; but towards the end of the evaporation, the Saccharine acid itſelf is, as he thinks, decompoſed, and hence the origin of the fixed air, which is nothing elſe but the oxygenous principle united with charcoal."

On this paſſage Mr. *Kirwan* makes the following remarks:

" Firſt,

pulverized crystals of tartar are put into a pewter kettle with 8 or 10 pounds of water and boiled. After this it is my practice to substitute oyster-shells cleaned and

"First, That according to this theory, the acid of sugar and fixed air should be one and the same thing; since both are composed of the oxygenous principle united to charcoal. M. *Lavoisier* may reply, that the acid of sugar, besides charcoal and the oxygenous principle, contains also inflammable air; but then he must own that the sugar contained a larger proportion of inflammable air than was given out during the formation of the acid of sugar, and cannot deny that part of this inflammable air united with the nitrous basis and formed nitrous air. He may perhaps also say, that this charcoal is different from common charcoal: but if so, how came it to make fixed air like common charcoal? Besides, if it were a different sort of charcoal, the acid of sugar should in his system be decomposed by common charcoal and sugar regenerated: for, according to his table, charcoal has a much stronger affinity to the oxygneous principle than sugar has to that principle. Nay, sugar should be regenerated by various metallic substances, which, by his table, stand before it in the order of attraction to the oxygenous principle.

Secondly, If the acid of sugar consisted of sugar itself united with the oxygenous principle, this acid would weigh more than the sugar itself of which it is formed, notwithstanding that some fixed air and inflammable air escape from it. For in M. *Lavoisier's* Experiment, the quantity of sugar employed was 236,25 grains, the quantity of the oxygenous principle taken up was 83 gr. So that if there had been no loss, the whole quantity of Saccharine acid would have been 319,25; and if we deduct the loss of 50 gr. of fixed air, and one gr. of inflammable air, we have still 268,26 gr. that is 32 gr. more than the weight of the sugar. But this increase of weight is contrary to the experience of all who have examined the matter with any accuracy. M. *Bergman* from three parts of sugar obtained but one of Saccharine acid: Mr. *Chaptal*, from $\frac{1}{3}$ to $\frac{2}{5}$ of the quantity of sugar employed:

M. *Sage* only $\frac{10}{16}$, and yet if we consider the proportion and strength of the acid employed by M. *Lavoisier*, we shall find it very improbable that even the whole of the sugar that he employed was converted into Saccharine acid.

Thirdly, If the Saccharine acid consisted of sugar undecomposed, and barely united with the oxygenous principle, then it should be formed by treating sugar with the black calx of manganese, or with the dephlogisticated marine acid; for both these substances contain abundance of the oxygenous principle, and easily give it out: yet after various trials, neither M. *Scheele* nor M. *de Morveau* were able to form a part of the Saccharine acid by means of either of these substances. This arises not for want of affinity in the oxygenous principle to sugar; for by M. *Lavoisier's* Table, the oxygenous principle has a greater affinity to sugar than to either of these substances, and passes from thence to sulphur, to which by that table it has a weaker affinity, as M. *de Morveau* has shewn. The only reason then, why sugar cannot be converted into an acid by those substances, is, because neither of them can strip it, and carry off that quantity of phlogiston which it must lose before it can become an acid.

Lastly, If the acid of sugar be distilled, it is wholly converted into water, fixed air, and inflammable air, and not a particle either of coal or dephlogisticated air is found in it. It is not therefore reasonable to look on either of them as its constituent principles."

and reduced to a coarſe powder, for the chalk uſed by *Scheele* and *Retz*, throwing the powder by little and little into the liquor, till the effervescence ceaſes: for which purpoſe I find nine ounces of the oyſter-ſhells juſt ſufficient. The liquor is then filtered and evaporated to dryneſs, when from 15 to 16 ounces are obtained of a good ſoluble tartar of a white colour. The matter remaining upon the filter is then elixated afreſh with water, and the liquor paſſed through the filter. After this ten ounces of concentrated vitriolic acid are diluted with eight or ten pounds of pure water in a large unglazed veſſel of ſtone-ware. To this liquor, the earthy reſiduum remaining upon the filter, which reſiduum is nothing elſe than a *calcareous tartar*, by ſome called Tartareous Selenite, is then added by little and little, and the whole, after being well ſtirred, left to ſtand in a gentle heat for the ſpace of 24 hours. After this the liquor is filtered again, and freſh water poured upon the reſiduum, till it is no longer acid to the taſte. The

The acid of ſugar is uncommonly ſharp, and 20 grains of it are ſufficient to make a gallon of water agreeably ſour. Boiling water diſſolves equal parts of this acid, but at 50° of Farenheit's thermometer, water diſſolves only half its own weight of it. Boiled with concentrated vitriolic acid, it is deſtroyed, while the latter acquires a brown colour: but the diluted vitriolic acid merely diſſolves it, ſo that the whole may be obtained out of it again by cryſtallization. The ſame circumſtance takes places with reſpect to the acetous, marine and nitrous; the latter of theſe, however, if the ſaccharine acid be diſſolved and boiled in it repeatedly, deſtroys it at laſt. 100 parts of ſpirit of wine diſſolved in a boiling heat 56 parts of it, in a moderate heat no more than 40. Profeſſor *Bergman* diſtilled equal parts of ſpirits of wine and of the ſaccharine acid together. The firſt products, in the beginning of the diſtillation, were an unchanged ſpirit of wine: but after this came over only a ſour-taſted ſpirit of wine, from which, by the addition of lime water, he ſeparated a ſmall quantity of ſaccharine æther, which was not inflammable, unleſs it were heated; and burned with a blue and white flame without affording hardly any ſmell. This was followed by an acid liquor and a little oil. The reſiduum amounted to about a fourth part of the acid employed, and being diſtilled again with four times its quantity of ſpirit of wine, yielded ſome æther and a little oil, leaving only $\frac{2}{3}$ of a brown cryſtalline reſiduum, which, expoſed to the fire, afforded a white ſmoke like the ſugar itſelf.

Vitriolic æther diſſolves, though not without difficulty, the cryſtallized acid of ſugar, which however unites both with expreſſed and diſtilled oils; but may be ſeparated from them again as well by cryſtallization as by a kind of ſublimation. Theſe cryſtals loſe their water of cryſtallization in a very moderate heat. When gently heated in glaſs veſſels, they yield, firſt their water of cryſtallization, which amounts to about $\frac{3}{10}$ of their weight. They melt in a more intenſe heat, and upon boiling grow brown. In a ſtill ſtronger heat, part of this acid is converted into fixed and inflammable air; another part paſſes into the receiver in the form of an acid liquor, while another more volatile part is ſublimed, and appears again in the form of ſmall cryſtals. [E]

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The whole of the liquor is then evaporated to dryneſs by a gentle heat in compact unglazed veſſels, and once more diſſolved in a ſmall quantity of cold water, in order to ſeparate from it the portion of ſelenite ſtill contained in it. After this it is filtered again, and ſuffered to evaporate very ſlowly; when at laſt fine white cryſtallized ſalt remains, which is the pure acid of Tartar*. From

As it is now clear that the acid of ſugar is the ſame as that which exiſts in the ſalt of wood-ſorrel, the French academicians have very properly beſtowed upon it the name of the *Oxaline* Acid; as in the oxalis (or wood-ſorrel) it is found in its native ſtate; whereas what was before called the Saccharine Acid is always factitious, and produced by art.

We cannot finiſh this note without taking notice of a glaring miſtake committed by almoſt every Engliſh writer or tranſlator who has had occaſion to mention the oxaline acid, which they have unanimouſly, as it were, agreed to call the acid of *Sorrel*, not conſidering, or not knowing that ſorrel is the Engliſh name for the *Rumex acetoſa* of Linnæus, a ſpecies of dock, of the Claſs and Order Hexandria Trigynia: another ſpecies of which genus is called the *Acetoſella* (Rumex Acetoſella), or *Sheeps Sorrel*: whereas the genuine Oxalis (or the *Oxalis Acetoſella* of Linnæus) which yields the acid in queſtion, is a beautiful Decandrous plant, growing almoſt always in woods and ſhady places, with a tender, bending ſtalk; a delicate white flower, the corolla of which is divided into five petals; and with three leaves, in form and diſpoſition reſembling clover. It flowers in April. It is called *Lujula* in moſt diſpenſaries, and makes an elegant conſerve, which is ſtill kept in ſome ſhops, and is called Conſerva Lujulæ. [E]

* To obtain this acid, Mr. *Dollfuſs (Pharmaceutiſch-Chemiſche Erfahrungen)* agreeably to *Scheele's* method, ſaturated three pounds of cream of tartar with a ſufficient quantity of waſhed chalk, of which, if the chalk is very pure, 14½ ounces will be requiſite. This calcareous tartar is then to be well waſhed, and afterwards digeſted with fifteen ounces of oil of vitriol diluted with a ſufficient quantity of water. The acid of tartar, diſengaged by theſe means, is next to be evaporated; during the evaporation, a quantity of ſelenite will detach itſelf from it by cryſtallization. This muſt be carefully ſeparated from the ſupernatant acid of tartar which muſt be ſtill farther evaporated, till ſome cryſtals appear upon its ſurface, when it is to be ſet by for cryſtallization. When, after ſome time, the cryſtals have been ſeparated, the acid is to be evaporated again; but after theſe have been collected for the ſecond time, the acid is apt to be of a brown colour, and is not likely to cryſtallize again, unleſs it be dephlogiſticated; which may be effected either by adding to it a quantity of ſpirit of nitre, and drawing it off again by diſtillation, or elſe in the method diſcovered by M. *Lowiz*, (Vide Chemiſche Annalen. 1786, p. 293) by the addition of a little charcoal, which, when boiled with the acid, renders it quite colourleſs, and enables it to cryſtallize.

M. *Schiller* in the Chemical Annals for 1787, Vol. I. page 544, has given ſtill more ſimple, as well as leſs troubleſome proceſs for procuring this acid. It is as follows: One pound of cream of tartar boiled in five or ſix pounds of water, a quarter of a pound of clear and colourleſs oil of vitriol is to be added by little and little, when a complete ſolution is obtained: if the coction

From the quantity of cryſtals above-mentioned I have generally obtained ten ounces of the acid ſalt. In order to be certain, that it is not contaminated with any vitriolic acid, a ſmall quantity of the ſolution of it is mixed with vinegar of lead, when a copious precipitation will enſue. If a little nitrous acid be added to it, the whole of the lead-precipitate will be perfectly diſſolved, in caſe the acid was pure. But if it contained any portion of vitriolic acid, the precipitate will not be entirely diſſolved by this addition. In the latter caſe, either a ſmall portion of calcareous tartar muſt be added, or the ſalt muſt be diſſolved afreſh in cold water, and afterwards filtered and cryſtallized, ſo that the laſt portion of the remaining liquor, which is to be ſeparated from the cryſtals and left for a future operation, ſhall amount to one ounce only, or a little more. If for this purpoſe, inſtead of crude calcareous earth, well-burnt lime be employed, the whole of the tartar, according to *Bergman*, is deſtroyed, and all its acid united with the above-mentioned calcareous earth, ſo that the remaining liquor contains nothing but cauſtic alkali, together with a conſiderable portion of calcareous earth in a ſtate of ſolution, which calcareous earth, on the evaporation of the liquor, frequently coagulates the lixivium, and muſt be previouſly ſeparated by repeated dilution with water, and by filtration. As no ebullition enſues from the addition of the quick-lime, and its union with the acid of tartar, it is extremely difficult to hit the point of ſaturation exactly. From this circumſtance, by a larger proportion of the vitriolic acid alſo, it is eaſy to infer that the tartareous acid is expelled from the calcareous tartar. This acid differs very remarkably from the acetous in the following particulars; firſt, that it concretes in the form of cryſtals; ſecondly, that it has not an acid ſmell; that, with calcareous earth, it produces a ſalt of different ſolution, called Calcareous Tartar, and with fixed alkali, regenerated tartar: it likewiſe contains more oil and earth in its compoſition than the acid above-mentioned, for which reaſon, when ſubmitted to a dry diſtillation, it yields an acid ſpirit and oil, in which caſe however the greateſt part of the acid is deſtroyed, ſo that there remains a mere coal without any ſaline matter. It is alſo ſeparated, viâ humidâ, by

coction be continued, all the vitriolated tartar is precipitated. When the liquor is evaporated to one half, it is to be filtered; and if upon farther evaporation, any thing more is precipitated, it muſt be filtered again: the clear liquor is then to be reduced to the conſiſtence of a ſyrup, and ſet in a temperate, but rather warm place; when very fine cryſtals will be formed, and as much acid will be obtained as is equal in weight to half the weight of the cream of tartar employed. It muſt be obſerved, that if too ſmall a quantity of vitriolic acid has been uſed, the undecompoſed cream of tartar ſecedes from the liquor along with the vitriolated tartar. [E]

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the acetous acid, from its different combinations, as is the caſe with the ſolution of iron in tartar, and the combination of acid of tartar with fixed alkali. M. *Weſtrumb* has concluded, with great appearance of probability, that this acid is nothing elſe than a more phlogiſticated acid of ſugar, in like manner as the latter appears to be a more phlogiſticated acetous acid. The acetous acid conſequently ought to be conſidered as the original, ſimple vegetable acid.

The *Salt of Benzoe*, commonly known by the name of *Flowers of Benjamin*, is the third of this kind, and may be extracted from the reſin of Benzoe in three different ways. The moſt ancient of theſe three methods conſiſts in nothing more than a mere ſublimation, for which purpoſe this reſin is poured into a glazed veſſel, which is ſet in the midſt of red-hot coals, and covered with a large paper cone, which has a ſmall aperture at top; and in this manner the ſublimation is carried gently on, and by ſlow degrees. The white flowers, in this aſcent, adhere to the inſide of this cone like flakes of ſnow, which however grow gradually browner and browner. When one of theſe cones is full, another is ſubſtituted in its place; and in this manner the proceſs is continued till no more flowers aſcend. With greater eaſe, and in a greater abundance, this ſalt is obtained by a ſecond method, firſt employed by *Vigenerus*, in which the Benzoe is ſubjected to a dry diſtillation in a retort, when at firſt an acid phlegm, and afterwards the ſalt of Benzoe diſtills over in the form of a tallow-like ſubſtance, which immediately becomes ſolid in the retort. As ſoon as this appearance ceaſes, nothing but mere oil comes over, which is taken in another receiver, that the ſalt already obtained may not be ſpoiled by it. The tallow-like ſaline maſs is then diſſolved as ſpeedily as poſſible in a ſufficient quantity of boiling water, which is inſtantly filtered. As faſt as the hot liquor paſſes through the filter, the major part of the ſalt ſeparates from it by cryſtallization, ſo that a very inconſiderable quantity remains after the liquor is grown cool. The third method, which is the invention of M. *Scheele*, conſiſts merely in *extraction* and *precipitation*, and is as follows. Four ounces of freſh-burnt lime are ſlaked with a little water. Inſtead of lime too, the ſame quantity of purified fixed alkali may be employed, conformably to the idea thrown out by *Goettling*. It is then, together with one pound of Benzoe reduced to a fine powder, and eight of water, thrown into a pewter kettle, and the whole boiled half an hour over a gentle fire, and ſtirred continually. After this, the ſolution is filtered; what remains upon the filtre is boiled once or twice more with eight pounds of water; and laſtly, the reſiduum waſhed as much as poſſible with hot water.

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The two folutions are then boiled down together to two pounds, and after being filtered very clear, poured into a cylindrical glafs. A quantity of marine acid is then added to the liquor till it begins to tafte fourifh, immediately upon which the flowers of benjamin are precipitated, and the whole mixture acquires an agreeable flavour. It is then fuffered to ftand for fome hours, and afterwards paffed through filtering paper. The filtered liquor ftill contains a quantity of the diffolved flowers, which may likewife be collected by farther evaporation and cryftallization. The flowers are deprived of all adhering acrid matter by wafhing them with cold water. When this falt is wanted of a filver colour, it may be diffolved again in hot water, and fuffered to fhoot into cryftals. By this method, as *Scheele* obferves, from one pound of Benzoe are obtained fourteen drachms of falt, which is the fame quantity as is obtained from good Benzoe, by the niceft diftillation. This falt may alfo be extracted from Benzoe, by boiling water only: but in this cafe, the Benzoe that is left may be employed for other ufes*.

The number of animal, like that of vegetable acids, remains at prefent undetermined. Thofe we are beft acquainted with, are the acid of *fat* and *that* of *ants*.

The acid obtained from the *fat of animals*, which was firft difcovered by *Charras*, but with which we became better acquainted in confequence of the labours of *Grutzmacher*, *Rhades* and *Segner*, and whofe peculiar properties have been ftill further explored by Profeffor *Crell*, is totally different from that juft before mentioned. With the different alkaline falts and earths it forms quite peculiar neutral falts, which have not the leaft refemblance to the other known falts. With volatile alkali it produces a volatile concrete neutral falt, and with magnefia,

* Befides the abovementioned vegetable acids, M. *Scheele* has difcovered the acid of *Galls*, by us denominated the *Cecidic* acid. It appears to be a modification of the *Oxaline*; being convertible into that acid by being treated with the nitrous in the ufual method: vide *Scheele* in Chemifche Annalen, 1787, Vol. I. pag. 1. *Hermftadt*, Chem. Annal. 1785, Vol. I. p. 426. An acid has likewife been difcovered in *Cork* by M. *Brugnatelli*: Like the preceding, it is obtained by diftillation with nitrous acid. This acid alfo difcovers a ftrong attraction for lime; fo that it is in all probability, like moft, if not all the vegetable acids, a modification of the oxaline.

The acid of *Camphor* difcovered by M. *Kofegarten*, and that of gums and mucilages, found likewife in expreffed oils; a difcovery for which we are indebted to M. *Weftrumb*, of *Hamel* in *Saxony*; are, together with the Benzoic acid, fpoken of above, different modifications of the oxaline acid, and, like that, procurable by means of nitrous acid. [E]

or

or rather murioecia, an eaſily deliqueſcent ſalt. It precipitates ſilver and mercury from the nitrous acid; and the ſilver and mercury diſſolved in this acid, are not precipitated by the addition of common ſalt. In theſe properties it appears ſomewhat to reſemble the marine acid. But it ſeems alſo to partake in a great meaſure of the nature of vegetable acids, of which its intimate union with oleaginous particles, its deſtructibility in a fierce fire, and the non-deliqueſcent calcareous ſalt formed by it, are inſtances. It is procured * by means of many repeated diſtillations from ſuet, and the empyreumatic oil obtained from this ſubſtance, a ſmall portion of it only being ſeparated at each operation. In the ſame way, a ſimilar empyreumatic acid is obtained, according to the obſervations of *Neumann*, from *fat*; of *Macquer*, from *butter*; of *Homberg*, from *milk*, and the *blood* of ſuch animals as have warm blood, of all which acids the nature has not yet been inveſtigated with ſufficient accuracy.

The acid of *ants* is obtained in the following manner: Upon a great quantity of ants contained in a retort, water is poured, which is then drawn off to nearly half, and yields an acidulous water together with a ſubtle ætherial oil. What remains in the retort is put into a linen bag, and all the liquor preſſed out. Now this contains the greateſt part of the acid of the ants, together with an unguinous oil, which muſt be ſeparated from it. If this acid be required in its pure ſtate, the expreſſed liquor muſt be poured again into a retort, and the aqueous part drawn off from it by a gentle fire, and as ſoon as any acid drops make their appearance, the whole is to be received in a ſeparate receiver, and the diſtillation continued till an empyreumatic ſmell is perceived. The beſt and moſt convenient way of obtaining it in a concentrated ſtate, is to ſaturate the whole of the diſtilled acid liquor with alkali, then filter it, evaporate and diſtill it again with half its quantity of oil of vitriol. This acid alſo bears a reſemblance to the acetous acid in many of its properties. It is not fixed: it neither throws down a precipitate from the ſolution of ſilver in nitrous acid, nor that of calcareous earth in marine acid. It alſo diſſolves minium, and afterwards, yields cryſtals reſembling the ſugar of lead. Iron and zinc are likewiſe diſſolved by it very briſkly, and from both theſe ſolutions ſolid cryſtals are obtained. In how far thoſe acids, which may alſo

* This acid, like all the other occult vegetable and acids, does not appear to exiſt previouſly in the bodies, whence they are procured: but to be formed in the operation by the air uniting with the heat of the ſubſtance that furniſhes the baſe of the acid. [E]

be extracted by distillation from other insects: such as *flies*, *bees*, *wasps*, &c. are of a similar nature, cannot as yet be absolutely determined*.

The second Class of salts is formed by the *alkaline salts.* Like the acids, they are generated by Nature alone, and possess a very peculiar lixivious taste. In their ordinary state, they effervesce with all kinds of acids on account of the considerable quantity of aerial acid which they contain, but which is expelled from them by every other acid. In the next place, they deprive all other acids of their proper specific taste; but at the same time lose their own, thus producing neutral salts. Farther, in consequence of their bearing the strongest affinity to acids of any other substance, they precipitate all earthy and metallic bodies that have been dissolved in acids; even though at the same time the body dissolved cannot be decomposed by the neutral salt generated in the process, nor by the addition of superabundant alkali. They change the blue juices of most vegetables to a green; but deepen only the blue colour of tincture of Litmus. These salts are either *fixed* or *volatile.*

The *fixed alkalies* expel the volatile alkali every where from its combinations with acids, on account of their greater affinity with the latter. In the humid way, they unite with all kinds of fat and unguinous substances, and render them miscible with water. In a red heat, they dissolve all kinds of earth, especially the filiceous. In this latter property lies the foundation of an error, which has induced us to believe, that the alkali, by frequently repeated solutions, evaporation, and urging it with a red heat, might be converted into an earth. This earth, in every instance, proceeds either from the crucible, or from the water which was used for the operation. Hitherto there are but two different fixed alkalies known in Nature, viz. the *mineral,* and the *common vegetable* alkali.

* The most circumstantial and best Treatise on the acid of ants, is that by *Arvidson*, (vide *Bergman's* Opusc.) with which may also be collated *Buchholz's* method of preparing this acid, published in the *Neuste Entdeck. in der Chemie*, Vol. VI, pag. 61. *Arvidson's* method of extracting this acid has some advantage over that of *Marggraf*, which we have given above. His method is this: The ants being put into a linen bag tied up close, are twice infused in boiling water, by which means all their acid goes over into the water. From this liquor as much of the pure acid is abstracted in a glass retort, as far as can be done without burning the residuum. (Vide also *Hermstadt's Remarks on the preparation of the acid of ants*, in *Chem. Annal.* Vol. II. pag. 209—219.

The

The *mineral* alkali is diſtinguiſhed from the other by a leſs fiery taſte *. Neither does it deliqueſce when expoſed to the air, but only falls to a powder, and conſequently loſes its own water inſtead of attracting any from the air. In cryſtallization, it admits more water into its cryſtals than any other ſalt. One pound of it contains from ten to twelve ounces of water. But the great difference between this and the vegetable alkali, is principally made to appear by uniting it with acids; when neutral ſalts are generated totally different from thoſe compoſed of the vegetable alkali. Some of the neutral ſalts ſo produced, ſtill exhibit veſtiges of the properties by which this ſalt is diſtinguiſhed; ſince they have not that tendency to deliqueſce which the others have: but rather fall to powder when expoſed to the air. It is not long ſince native mineral alkali has been diſcovered in its pure ſtate; but, conſidered as the baſis of different ſalts, it was taken for an earth, till the method of ſeparating it from them was diſcovered, when its peculiar alkalino-ſaline character was univerſally acknowledged. It is almoſt incredible, that the former opinion, which was that of *Stahl*, *Junker*, *Neumann*, *Pott* and others, ſhould ſtill have been ſupported, after this ſubſtance had been clearly deſcribed as a native alkali, by *Hierne* and *Du Hamel*; till at length *Marggraf* put this point out of all controverſy.

This ſalt is to be met with tolerably pure in large quantities, in ſeveral places. It is found in abundance, and even uſed for various purpoſes in *Egypt*, *China*, *Perſia*, in the environs of *Smyrna* and *Tripoli*, and, in general, all over the eaſt, as well as the northern coaſt of *Africa* †, in *Hungary*, and *Siberia*.

* The vegetable akali is generally united with a leſs quantity of aerial acid, and is conſequently in a more cauſtic ſtate, which ſufficiently accounts for this difference in the taſte. [E]

† We are indebted to M. *Chr. Bagge*, Swediſh Conſul at Tripoli, for the beſt account hitherto publiſhed of the native mineral alkali, which he has inſerted in the Tranſactions of the Academy at Stockholm, and which, being ſhort and conciſe, we ſhall give the tranſlation at full length: "Dr. *Donald Monro* has committed frequent miſtakes in his Deſcription of *Trona* in the Philoſophical Tranſactions. Its native country is the province of Suckena, which belongs to Tripoli, and is two days journey from Faizan. It is found at the foot of a rocky mountain upon the ſurface of the earth, in a cruſt about an inch thick, or ſometimes not thicker than the back part of a knife. It is always found in a cryſtalline ſtate. When broken, it exhibits compact, oblong, parallel, ſometimes oblique, at other times radiated cryſtals, like uncalcined Gypſum. Its lower ſurface ſeems to conſiſt of the grey earth itſelf, which however, as well as the cryſtalline part, efferveſces with acid, and has a ſaline taſte. The Blacks take about the ſize of a walnut of it, by way of a purge, for the cholic, and boil it up with a tea cup full of oil of olives. This maſs becomes hard when cold. They then break it into pieces, and ſwallow it, waſhing it down with water. They mix it likewiſe with their ſnuff, and prefer this ſnuff to rapée.

Beſides the great quantity of this ſalt, which is annually carried to Nigritia and Egypt, fifty

*Siberia.* It likewiſe occurs in many of the mineral waters of *Germany.* Conſequently it is a native ſalt, and the true *Natrum* of the ancients, of which now there can no longer remain the leaſt doubt. It is ſometimes found likewiſe adhering in a ſtate of efflorеſcence to plaiſtered walls; in which ſtate it is called *Aphronitrum*, or *Halonitrum*, though every ſalt that effloreſces in this manner, is not to be conſidered as ſuch. It is eaſieſt and moſt commodiouſly obtained from *Soda*, which is the mere aſhes (abounding in ſalts) of various marine plants, which in different countries in the ſouth of *Europe*, are burned for the purpoſe of extracting this ſubſtance from them*. The Soda of *Alexandria* is reckoned the beſt; next to which, in point of quality, is that of *Alicant* in *Spain*. The Reader muſt not be ſurpriſed at the appellation of *mineral* being given here to the alkali extracted

fifty ton are brought every year to Tripoli. It is not mixed with ſea-ſalt. The ſea-ſalt-pits are by the ſea-ſide; and the Trona is 28 days journey up the country. This ſalt is far preferable to pot-aſh and barilla for the purpoſe of waſhing linen, and making ſoap; and it ſeems to be much more innocent than either of theſe ſubſtances for waſhing cotton, as it is never cauſtic, though it is 50 per cent ſtronger than Soda." Vide Memoirs of the Academy at Stockholm, Tom. XXXIV. p. 140.

In a former volume, viz. Tom. XXXIII. p. 170. M. *Grill Abrahamſon* gives another account of the native mineral alkali, wich he received of *Joſeph Vit Kuo*, a Chineſe by birth, and now a Catholic Miſſionary, who gave him the following Deſcription: "There is an earth in the kingdom of Hami in Tibethian Tartary, which is much like the Kien, or Chineſe ſoap. It has a ſaline taſte. Three feet below this earth, there is a natural white ſalt very hard, ſurrounded with the earth and encruſted with it. In all places whatever, where the ſurface is white, and the earth light, there is either ſalt, or kien, or a kind of natural borax under it, which may be readily diſcovered by the taſte. By boiling the earth the ſalt is got out of it; but the borax is formed naturally, and cannot be obtained from the earth by coction."

M. *Guſtavus Engſtrom* made ſome experiments with this ſalt, which ſhew that it is a native alkali. Stockholm Tranſact. l. c.

We muſt here take the liberty of remarking, that the utmoſt endeavours ſhould be uſed to get the mineral alkali at a cheaper rate than it is at preſent, either in the way of trade, or by holding forth proper encouragement to chemiſts to ſeparate it from ſea-ſalt in a leſs expenſive mode than has been hitherto done. The manifold utility of this ſalt in our manufactures is too obvious to require a particular detail. The circumſtance of its never being cauſtic when in a cryſtalline ſtate, would give it a great preference over the vegetable in blanching our cottons and linens. The preference given to this alkali by the ſoap-boilers, is too well known to be here inſiſted on. It keeps the ſoaps hard and dry; as it does not, like the other alkali, attract moiſture from the air. And the greateſt chemiſts are agreed, that the mineral alkali is much preferable to the vegetable alkali in the glaſs manufacturing, as the former makes a much harder and better glaſs, which is not ſo ſubject to be corroded by acids, and does not grow ſo foul by long expoſure to the air, as that made with vegetable alkali.

* For this purpoſe are uſed the *Salſola Soda* Linn: the *Salſola Kali*, and the *Salicornia Europæa*. [A] In *England*, theſe aſhes are better known by the name of *Barilla* aſhes or *Barillas*. [E]

from

from theſe vegetables; for this ſalt has beeen introduced into them from the earth, and therefore derives its origin from the mineral kingdom, and beſides is ſimilar in every reſpect to the alkali, which is more directly obtained from this kingdom. But as ſoda, beſides the mineral alkali, generally contains a portion of common vegetable alkali, and likewiſe a quantity of undecompoſed marine ſalt, in the ſeparation of the former from the ſoda regard ſhould be had alſo to this circumſtance.

In order to ſeparate the mineral alkali from ſoda, the ſoda is reduced to a coarſe powder, and boiled with a ſufficient quantity of water, till the latter ceaſes to take a ſaline taſte from it. The filtered liquor is then evaporated to the point of cryſtallization; filtered again, and ſet by to cryſtallize. In the cryſtallization, care ought to be taken that other neutral ſalts, which may chance to be contained in the ſoda and the common alkali, do not mix with it at the ſame time.

Beſides this way, in caſe that the native mineral alkali cannot be had, one muſt endeavour to ſeparate this alkali from ſubſtances with which it is combined. Sea ſalt would yield it moſt copiouſly, if it could immediately be ſeparated from this ſubſtance, for which purpoſe, however, no attempt that has been hitherto made, has ever been attended with ſucceſs in any great degree. Next to this, Glauber's ſalt is of all others the fitteſt. Dr. *Delius* affirms, that from a ſolution of Glauber's ſalt with which quicklime had been digeſted for this purpoſe, he obtained, on the ſecond and third cryſtallization, the cryſtallized mineral alkali; an experiment which has alſo ſucceeded with me, on my treating in the ſame manner one pound of quicklime; the weight however of the alkali thus procured is inconſiderable. It may be obtained alſo in the method recommended by *Du Hamel*, by fuſing Glauber's ſalt with powdered charcoal, and thus converting into liver of ſulphur. This maſs is afterwards to be diſſolved in water, the newly generated ſulphur precipitated with vinegar, the lixivium ſeparated from it by filtration, to be inſpiſſated by boiling; and the reſiduum made red-hot. From this coaly reſiduum, the pure mineral alkali may be obtained by elixation and evaporation. Inſtead of vinegar alſo, the nitrous acid may be uſed in the precipitation, and the ſalt which has been obtained from the evaporated lixivium, be detonated with coals like any other cubic nitre, in the method preſcribed by *Marggraf*; when the mineral alkali remains behind in the crucible pure and uncombined with any other ſubſtance. Hither is likewiſe to be referred the method deſcribed by Profeſſor *Crell*; purſuant to which he diſſolved one ounce of chalk in about a gallon of beer-vinegar, and continued pouring Glauber's ſalt into this ſolution, till there was no longer any precipitation of ſelenite to be obſerved; for which purpoſe he fuſed $1\frac{1}{2}$ ounce of the ſalt. From the liquor when filtered he obtained cryſtals

of terra foliata tartari, from which, after calcining and elixating it, and cryftallizing it afrefh, he procured 6¼ drachms of mineral alkali. There is yet another way to feparate this falt from Glauber's falt; viz. by mixing one ounce of it with four drachms of purified alkaline falt, diffolving them together in water, and evaporating the liquor, which firft yields vitriolated tartar, and at laft the mineral alkali*.

Concerning the origin, production, and compofition of this fubftance, but little can be advanced with any certainty. It ftill continues to be a mere hypothefis that the mineral alkali has magnefia for the bafis of its compofition, which opinion, fome Chemifts have been induced, with *Wenzel*, to entertain, by the confideration of the following phenomena†. And firft, it is a well known obfervation of *Marggraf*, that the folution of magnefia in the nitrous acid has that property, that paper, which has been fteeped in it, and dryed again, burns with a green colour. Now when this experiment is collated with thefe others, viz. that Glauber's falt when mixed with powdered charcoal, and thrown into a red-hot crucible, likewife exhibits a green flame; and that one part of flowers of fulphur projected into a red-hot crucible, with from eight to twelve parts of cubic nitre, will in like manner yield a green flame; and when at the fame time it is confidered that both thefe neutral falts contain mineral alkali, it is natural to fuppofe that the fimilarity of the colour of the flame in thefe neutral falts may proceed from the earth which forms the bafis of the mineral alkali, and that this earth is probably no other than magnefia.—Native uncombined mineral alkali, as well that which is merely found in the earth, as that which is obtained from foda, feems to derive its origin from fea falt. But here a queftion arifes, what is become of the acid? My idea on this fubject, is as follows: The marine acid is either feparated from the alkali during the paffage of the neutral falt through the earth, which alkali is afterwards by the liquids by which it is diffolved, introduced into the vegetating plants; or elfe the whole falt goes over into the plants unchanged; but is there, by the peculiar nature of their juices, divided into its conftituent parts: or, finally,

* According to M. *Meyer*, the mineral alkali may alfo be feparated from common falt by the addition of vegetable alkali: I have convinced myfelf of the truth of this by making the experiment myfelf; but I found that more than an equal weight of the latter, and indeed nearly one fourth more muft be taken for this purpofe. Chem. Annal. Vol. II. pag. 125.

† Since the publication of the Chevalier *de Lorgna's* obfervations, in the *Journ. de Phyfique*, and the experiments of M. *Ofburg* inferted in the Act. Acad. Mogunt, 1784—5, p. 8: it has been fuppofed by many, that the mineral alkali is compofed of magnefia or murioecite, and the vegetable of lime combined with phlogifton, to which, confidering that volatile alkali is feparable by heat from fixed alkali, and therefore the one convertible into the other, fome add mephitis. [E]

ſome other ſubſtances mix with it here; by means of which only it is that its conſtituent parts loſe their ſtrong coheſion: ſo that, in caſe of combuſtion, the acid part is ſeparated and diſperſed in the air, while the mere fixed alkali only of the ſea-ſalt remains behind. The marine acid found in the Egyptian ſoot, ſerves to illuſtrate this opinion, as alſo the following circumſtance, viz. that ſoda, beſides mineral alkali, commonly contains ſome unchanged marine ſalt. It is alſo poſſible for the marine acid to be expelled from the common ſalt by the vitriolic acid, and for the Glauber's ſalt thus formed, in its farther paſſage through the earth to depoſit the vitriolic acid in it, and for the mineral alkali to be thus ſet at liberty. It is certain, that in ſeparations of this kind, Nature by far ſurpaſſes art.

The *common vegetable* alkali is diſtinguiſhed by various peculiar properties, from the mineral alkali. It ſeems to have more of the matter of fire in its compoſition: hence it has a much ſharper taſte than the other, and alſo deliqueſces eaſier on expoſure to the air. The liquor obtained from it, is very improperly called *Oil of Tartar*; it being nothing but ſalt of tartar liquefied by the humidity of the air. This great attractive power proceeds from the loſs of a certain portion of aerial acid, and at the ſame time alſo from a certain quantity of the matter of fire, which ſtill adheres to this ſalt in conſequence of its having been urged with a red heat. This too is the reaſon why it cannot be brought to cryſtallize with the ſame eaſe as the mineral alkali is; a fact which formerly has been denied by many, and is indeed ſtill diſputed by ſome. Nothing more however is requiſite for the expulſion of the matter of fire which ſtill adheres to it, than ſaturation with the aerial acid, or a continued gentle heat. A ſtrong ley of the pureſt alkali of tartar needs only be placed, well covered up, near a ſtove in winter; and it will, after a ſlow evaporation of the moiſture, form cryſtals, which will afterwards, like the cryſtals of ſoda, remain conſtantly dry in an air that is not too moiſt. This cryſtallization may be ſtill more promoted, as *Cartheuſer* obſerves, by pouring into a ſtrong ſolution of pure alkali, nearly one fourth of ſal ammoniac which has been prepared with fixed alkali, and then drawing it off again by diſtillation, when the remaining alkali that is left behind, will very quickly concrete into cryſtals. A third method is, to throw a ſtrong ſolution of pure fixed alkali into a quantity of aereal acid, which has been extracted from crude calcareous earth, fixed alkali, or from any other convenient ſubſtance, by fire, acids, or fermentation. The neutral ſalts, generated by this with acids, will not fall to powder in the air, in the ſame manner as mineral alkali does: with ſome acids, it even forms deliqueſcent ſalts. Its attractions for the vitriolic—nitrous—and marine acids is ſtronger, than is that of the mineral alkali for theſe acids.

It has not as yet been found native in an uncombined ſtate. It is chiefly contained in the vegetables, of the juices of which it forms a material conſtituent part. When they are burned, it remains behind in their aſhes. Hence too it is commonly obtained from the aſhes of many vegetables, and their different parts; eſpecially from herbs, woods, and roots *. For this purpoſe the aſhes of them are elixated with a ſufficient quantity of water, the lixivium evaporated to dryneſs, and the remaining ſalt heated to incandeſcence in a particular kind of furnace. Though all kinds of wood yield this ſalt in their aſhes, one kind however yields a greater quantity than another, as may be ſeen in the Short table annexed.

| | | lb. | oz. |
|---|---|---|---|
| ¼ Cord of | Hornbeam yields of calcined ſalt - | 1 | 7 |
| ——— | Beech - - - | 0 | 13 |
| ——— | Alder - - - - | 1 | 4 |
| ——— | Birch - - - | 0 | 11½ |
| ——— | Maple - - - - | 2 | 8½ |
| ——— | Willow - - - | 0 | 8 |
| ——— | Aſh - - - | 1 | 2 |
| ——— | Oak - - - - - | 0 | 13 |
| ——— | Elder - - - - | 1 | 8 |

The ſalt extracted from the aſhes of vegetables has at different times obtained different names. The kind of ſalt extracted from aſhes, which is moſt generally uſed and prepared in large quantities, is *pot-aſhes*: we frequently meet alſo with the names of *ſalt* of *tartar*, *cendres gravellées*, and *pearl-aſhes*, all which however differ from each other in certain particulars.

Moſt of theſe ſalts, extracted from the aſhes of vegetables, do not conſiſt of pure alkaline ſalt; but generally a part of them has been changed in the plants themſelves, previouſly to their combuſtion, into a neutral ſalt by the vitriolic and marine acids; hence commonly there is found in pot-aſh a portion

* In the Northern Countries of Europe, where wood grows in great abundance, it is burned for the ſake of obtaining the Pot-aſh. The proceſs is as follows: Firſt, They burn the wood in large pits to aſhes. Theſe they pile up, ſtratum ſuper ſtratum, along with ſome green wood, to prevent them from falling down, and then ſet fire to the whole pile again, repeating this procedure ſeveral times, till the aſhes are become very hard. They then elixate the aſhes with boiling water, pour off the ley, evaporate it to dryneſs in large iron boilers, and laſtly, calcine it in furnaces conſtructed for the purpoſe. The beſt aſhes are obtained from beach and birch; the worſt of all from oak, on account of its being of ſo oily a nature. Among the herbs, the *common fern*, or *female brakes*, (the pteris aquilina of Linnæus) yields the greateſt quantity of this ſalt, and even more than any kind of wood hitherto known. [D]

of

of vitriolated tartar, and digestive salt. This is the sole cause of the difference which is observed between these different incinerated salts, in proportion to the greater or lesser quantity of such neutral salts contained in them. And therefore it is by no means indifferent in all cases what alkaline salt is made choice of for the various operations of chemistry *.

Of all these alkaline salts the purest is *salt of tartar*, particularly that which is obtained from tartar by first reducing it to a perfect coal; and afterwards elixating it; and lastly, by filtration, and evaporation of the lixivium. For this reason this alkali solely ought to be used in those experiments, in which great accuracy and precision is necessary; though after all, strictly speaking, it is not perfectly pure, but is contaminated with a small portion of marine acid †.

*Cendres gravellées* are prepared from the calcined lees of wine, or burnt vine-stalks. This substance has obtained the name given them in Germany, viz. *Woad-ashes*, from their having been chiefly employed in former times for dying with woad. The alkali contained in them is very pure; but they cannot be had in great abundance in Germany. It is said that they prepare this substance in large quantities in France, whence it is exported to other countries.

Under the appellation of *Pearl-ashes* are understood pot-ashes which have been dissolved in boiling water, and strained off, then boiled down again, and a second time urged with a red heat; in short *purified pot-ash*. One pound of this salt is the produce of about 700 pounds of beech wood.

Now, since in the way we have mentioned, all ordinary salt of wood-ashes whatever, which occurs under the name of pot-ash, is rendered impure by the admixture of different neutral salts; it is necessary for the chemist, in every case, to detach these neutral salts from the genuine alkaline salt contained in pot-ash; and to obtain the former from it in its utmost purity. This is effected by a cold extraction of the pot-ash with a small quantity of water. With this view, upon one pound of it may be poured an equal

* Besides the salts above-mentioned, pot-ash is very often mixed with calcareous earth by those who manufacture it, during the process for extracting the salt. But the addition of sand, which some manufacturers make during the calcination, is an adulteration of still greater consequence, as this substance combines so intimately with the alkali as to becom insoluble in water. The only means of separating the siliceous earth is to expose a solution of the alkali for a few weeks to the open air, during which time it will absorb fixed air from the atmosphere, and precipitate the earth. Pot-ash, to be pure, must not precipitate any earth on the addition of an acid. [D]

† If crude tartar be burned with proper care and attention, 2½ parts of it will yield one part of pure vegetable alkali. Vide *Bergman* On the Usefulness of Chemistry. [D]

weight

weight of water, which, after they have ſtood together ſome time, is filtered and evaporated to dryneſs. And thus is obtained *purified alkali*, or the pure *ſalt* of *pot-aſh*. In this mode of extraction, it is true, the greateſt part of that portion of neutral ſalt, which is of difficult ſolution, remains behind undiſſolved; but yet the alkali, thus purified, cannot, taken in a ſtrict ſenſe, be conſidered as a perfectly pure alkali; becauſe ſtill, notwithſtanding all this precaution, the digeſtive ſalt, which is very ſoluble, and even a ſmall portion of vitriolated tartar, are diſſolved together with the alkaline ſalt. And though this purified alkali is not in all caſes ſufficiently pure for the uſe of the chemiſt, yet ſtill it may be ſafely employed with this view for every pharmaceutical purpoſe.

In fine, this kind of vegetable alkali, ſetting aſide the ſubſtances combined with it, is the ſame in all vegetables which do not contain the mineral alkali. It ſeems, however, that in herbs it is frequently combined,, ſometimes with the vitriolic---ſometimes the nitrous---and at other times with the marine acid. In many herbaceous plants, it is even entirely ſaturated with them, as I found to be the caſe with reſpect to the colts-foot, in which there was not the leaſt particle to be found of uncombined alkali. Vegetable ſalts of this kind, which are obtained by combuſtion, ceaſe to poſſeſs any of the ſpecific powers of the vegetables themſelves. Neither have the *Tachenian* ſalts, which are obtained from plants by burning them under cover with a ſmothering flame only, and afterwards elixating the coaly reſiduum without previouſly calcining it, any advantage in this reſpect, if we ſet aſide the empyreumatic oleaginous particles that remain in combination with the ſalts.

The vegetable alkali is likewiſe ſolely produced by nature; the ancient erroneous opinion, of its being artificial and generated by fire, has been proved to be without foundation. What *Beaumé* alſo has advanced with reſpect to its having been compoſed by art, of lime and the coal of oil of hartſhorn, is abſolutely falſe; and all that can be inferred from the experiment is, either that the operation was not performed with the due regard to cleanlineſs, or that an alkali, as from comparing ſeveral paſſages of his works with each other, I have reaſon to ſuppoſe, is contained in the limeſtone of his country. For the reaſons already mentioned, I ſtill to this very moment continue abſolutely to deny the poſſibility of an artificial production of this ſalt. As to the natural and original compoſition of it, we can only *conjecture*, that calcareous earth forms the baſis of it. Various ſimilar effects of quick-lime ſeem to give force to this opinion; it is likewiſe worthy of obſervation, that the two neutral ſalts, vitriolated tartar, and Glauber's ſalt differ as much from each other, with reſpect to

their

their ſolubility in water, as do the two neutral ſalts which are prepared from the vitriolic acid with calcareous earth and magneſia, namely Selenite and Sal Catharticus amarus. But in what manner this earth, which forms the baſis here, is ſo intimately united with the pure matter of fire, and is, with air and water, converted into a ſalt by, what may be termed in the ſtricteſt ſenſe, the operations of nature; this will probably, together with the proportion of theſe parts, for ever remain a ſecret to us. *Hagen's* opinion, therefore, that the vegetable alkali derives its origin from the mineral alkali of ſea-ſalt, appears to me not at all probable, as we have not the leaſt proof that nature is uſed to proceed in this manner, and forms the other kinds of ſalt from one particular ſalt only, which ſerves for a baſe to them. In fact, her operations are by no means confined within a circle as narrow as that which limits the labours of the artiſt. Hence it is probable that ſhe produces both the one alkali and the other directly from the ſimpleſt elements, though by a diverſity in their proportions, and in the manner of their union.

The third ſpecies of alkaline ſalts, viz. the *volatile* alkali, is to be found in all the three kingdoms of nature, and is entirely, whenceſoever it is derived, of one and the ſame quality. It is extracted in the greateſt quantity and moſt commodiouſly from animal ſubſtances. In vegetables, from which alſo it cannot ſo readily be ſeparated, it ſeems to abound ſomewhat leſs: in the mineral kingdom, it is certainly contained in great quantities; although, compared with the amazing bulk of the earth, the quantity of this ſubſtance, on account of its being greatly diffuſed, appears to be but very ſmall. Indeed it ſeems properly to derive its origin from the mineral kingdom, from whence it firſt paſſes into vegetables, and from thence into animal bodies. The native ſal ammoniac, which is thrown out by volcanos, is a very clear proof of this. In the natural ſtate of bodies, it is, excepting in very few caſes, not perceptible to the ſenſes, on account of its being every where ſtrictly combined with acids and other ſubſtances; and this is the reaſon why ſo long a time elapſed before the exiſtence of it was diſcovered. On this account it muſt always be ſeparated by an evolution of the combination before-mentioned, which in bodies of the mineral kingdom may be effected by fixed alkali, or quick-lime; but in the organized bodies of the two other kingdoms, either by the addition of theſe ſubſtances, or elſe by fire or putrefaction. Beſides its general alkaline properties, it is diſtinguiſhed by a ſtrong volatile ſmell, and by the circumſtance that it is not fixed, like the others already mentioned, but makes its eſcape into the air in its free and uncombined ſtate, on the application of even the moſt gentle heat. Inſtances, however, will ſometimes happen, where uncombined volatile alkali, on account of the

ſmallneſs of its quantity, cannot be diſcovered by the ſmell. In ſuch caſe, recourſe muſt be had to one of its properties, which is this; that on the approximation of this ſubſtance to fuming acids, ſuch as the nitrous, marine, and acetous acid, it will form with them a viſible vapour. It muſt not however be inferred from this, that the production of ſuch a vapour is always a ſign of the preſence of volatile alkali, becauſe the cauſtic fixed alkalies will produce the ſame phenomenon, if they are brought near the above-mentioned acids. Copper and nickel are diſſolved by this alkali with a deep blue colour. United with acids, it generates neutral ſalts that are volatile. With reſpect to its compoſition, it ſeems to differ from the fixed alkalies in this, that it contains leſs earth than they do, and more phlogiſton.

In the mineral kingdom, the volatile alkali is found in lime-ſtones, the lapis ſuillus, chalk, marble, coals, turf, loam, clay, and a great many other kinds of earth. Its exiſtence in all theſe bodies may commonly be demonſtrated merely by diſtilling them with a briſk fire; and better ſtill, if, before the diſtillation, a quantity of fixed alkali, or quick-lime, be added to them. It has even been found in all mineral ſalts and their acids, in vitriol; for inſtance, nitre, common ſalt, and their reſpective acids, as alſo in gyps and ſulphur, and ſeparated by means of lime or fixed alkali. In the ſal ammoniac, which is found in ſeveral places, the preſence of this alkali is ſtill leſs controvertible.

Among the bodies of the vegetable kingdom, it is chiefly extracted by a dry diſtillation from muſtard-ſeed, the flowers and leaves of the elder, from the leaves of the wild cherry-tree, from white water lilies, tobacco, and ſage; and without doubt from many other plants. The plaineſt proof of its exiſting almoſt univerſally in the vegetable kingdom, is afforded by the ſoot of our chimneys, from whith a volatile alkali may always be ſeparated by a dry diſtillation.

But although this ſubſtance occurs both in the mineral and vegetable kingdoms, in the way we have juſt mentioned, nevertheleſs it is uſually ſeparated by diſtillation, eſpecially for medical uſes, from the animal kingdoms only, and more particularly from hartſhorn, as alſo from all other kinds of horns and bones; likewiſe from urine and blood. For this purpoſe the horns or bones are beaten to ſmall pieces; when an earthen or iron retort is filled almoſt full with them, the retort then incloſed in brick-work in a reverberatory furnace, and furniſhed with a capacious receiver. The fire muſt be gentle at the beginning, and but gradually increaſed, ſo that the receiver may never be heated by the vapours, which are expelled. At firſt, only aerial and watery vapours will come over, which however by degrees are impregnated with volatile ſalt and a thin oil. At laſt the

volatile

volatile alkali makes its appearance, and ſettles on the ſides of the receiver in a dry form, together with more oil of an empyreumatic odour, which, towards the end of the operation, paſſes over quite thick like tar. When with the fierceſt fire no more vapours ariſe from the retort, which may be known by the receiver's being heated no more, the operation is finiſhed. As ſoon as the veſſels become cool, the receiver is taken off; in which are found a watery liquor charged with volatile ſalt, with the oil ſwimming upon it, and the remaining portion of the volatile alkali adhering to the ſides. All the liquor, which is found in the receiver, is poured together into a ſeparating funnel, and the watery part, which is underneath, is allowed to ſeparate from the the oil, which is ſaved in a ſeparate veſſel. The watery liquor, which is called *Spirit of Hartſhorn*, together with the volatile alkali adhering to the ſides of the receiver, as both of them are ſtill greatly contaminated with empyreumatic oil, is poured into an alembic, when near an eighth part of clean ſifted aſhes being added to it, the alembic is covered with a capital, a receiver adapted, and the whole expoſed to a gentle fire in a ſand-pot. The *volatile ſalt* of *hartſhorn*, poſſeſſing a greater degree of volatility than the aqueous liquor, will ſublime firſt into the capital, of a perfectly white colour. Now as ſoon as it is obſerved that this ſalt ceaſes to ariſe, and that a liquor begins to come over, the fire is ſuffered to go out; the concrete purified ſalt is taken out of the head, and ſet apart for uſe. The head is to be ſet again upon the alembic, furniſhed with a receiver, and luted; and the whole of the liquor is now to be diſtilled over by a gentle fire as before, till the aſhes are become almoſt dry, and no volatile ſmell nor ſaline taſte are perceived in the liquor as it comes over. This is called *rectified ſpirit of hartſhorn*, of which the empyreumatic oil, that at firſt contaminated it, remains behind in the aſhes.

The volatile alkali, obtained in this manner, is ſtill combined with ſome of the empyreumatic oil, as will be immediately diſcovered by the ſmell. If however we wiſh to diveſt it entirely of this, and alſo to have that part of the volatile alkali, which is ſtill contained in the ſubſequent ſpirit, in a pure concrete ſtate, the trouble of the above-deſcribed rectification may be ſaved, and the whole ſaline mixture, immediately after its ſeparation from the oil, be ſaturated with vitriolic or marine acid, and afterwards filtered and evaporated to dryneſs. The concrete ſalt is then mixed with once and a half of its weight of chalk, or three times its weight of pot-aſh, and the pure volatile alkali collected in a concrete form in a ſmall receiver well luted to a glaſs retort*.

All

* Pure volatile alkali never exiſts in a concrete form. When volatile alkali is in this ſtate, it is always combined with ſome acid; and what is uſually taken for concrete volatile alkali, is a combination

All that is effected by this latter mode of purification is, preparing from the ſpirit of hartſhorn and its volatile ſalt, with the addition of an acid, a quantity of ſal ammoniac, which might have been bought cheaper, as may be diſcovered on calculating the expence and the quantity of the product obtained. This conſequently is by no means an advantageous method of procuring a pure volatile alkali; and for this reaſon ought not to be purſued. If an exceedingly pure alkali is wanted, it will anſwer better in every inſtance to extract it from ſal ammoniac, either in a liquid or in a concrete form. In order to obtain concrete volatile alkali, one pound of well-dried ſal ammoniac is mixed with twenty ounces of chalk, which has alſo been dried over the fire, and pulverized; or two pounds of ſifted wood-aſhes; or inſtead of this, three pounds of very dry pot-aſh: the whole is put into a retort, which being placed in a ſand-pot, a middling-ſized receiver is luted to it as cloſe as poſſible. Immediately upon this, all the volatile alkali is expelled from the ſal ammoniac with great caution, and with the requiſite degree of heat, which volatile alkali will be depoſited in thick incruſtations on the inſide of the receiver. The fire, on this occaſion, ought to be kept at ſuch a moderate pitch, as to prevent any part of the volatile ſalt from eſcaping through the junctures during its ſublimation.

As, agreeably to what we have already ſaid, there is no difference between this and the above-mentioned volatile alkali, ſeparated from hartſhorn, and other animal bodies, excepting that the latter is ſtill united with empyreumatic oil, it is eaſy to conceive, that the former alſo may be made perfectly ſimilar to ſalt of hartſhorn. For this purpoſe, it is only requiſite to mix one ounce of oil of hartſhorn with ſal ammoniac and chalk in the above-given proportion, and to expel the volatile ſalt in the mode juſt now deſcribed. This volatile alkali will be in no reſpect diſtinguiſhable from that which has been ſeparated from hartſhorn; and thus will be compounded an *artificial ſalt* of *hartſhorn*

But if the volatile alkali be required from ſal ammoniac in a liquid form, in

bination of the pure alkali with aerial acid, with which however it is not ſaturated. In conſequence of this, the concrete or cryſtallized volatile alkali efferveſces on the addition of almoſt any other acid; the aerial (formerly known by the appellation of fixed air) making its eſcape in the form of a gas, or permanently elaſtic vapour. This partially neutralized alkali is obtained, whenever any ſubſtance is uſed for its expulſion from ſal ammoniac, that contains the aerial acid, ſuch as chalk, or perfectly mild vegetable or mineral alkali; and the combinations is formed by means of a double elective attraction; the aerial acid paſſing from the chalk to the volatile alkali, at the ſame time that the marine acid quits the ſal ammoniac in order to unite with the lime of the chalk. But the common vegetable alkali, being nearly in a cauſtic ſtate, the volatile alkali comes over in a liquid form, being diſſolved in the water, from which it does not ſeparate by cryſtalliſation for want of a ſufficient quantity of aerial acid. [E]

this

this case chalk cannot be employed, but fixed alkali only is to be used. Both this and the sal ammoniac are to be put into a retort in the proportion above specified, with five pounds of water, and three pounds drawn off again from it by distillation with a gentle fire; which must be afterwards set apart under the name of *watery spirit of sal ammoniac.* (Spiritus Salis Ammoniaci aquosus.) But if, together with the above-mentioned salts, 3 lb. of spirit of wine, and 2 lb. of water be poured into the retort, and 3 lb. of this mixture be in like manner drawn off by distillation, a *vinous* or *dulcified spirit of sal ammoniac* (spiritus salis ammoniaci vinosus, vel dulcis) will be obtained.

Volatile alkali may also be drawn in great quantity, and tolerably pure, from urine. For this purpose, a quantity of urine is set apart for several months, especially in the winter season, to putrefy; and the flakes of ice, by which from time to time it is covered, (for it must be kept in a place where it cannot freeze to the bottom), are constantly taken off. This urine is drawn off by distillation in a retort, which has been previously filled within one fourth of its capacity with sifted ashes, nearly to half its quantity, or as long as the odour of volatile salt can be perceived. The distillation is yet better performed in a large copper alembic with a pewter head and worm. In both cases it is necessary to prevent the frothing up the urine by means of a little tallow put into the distilling vessel. According to the quality of the liquor, the first product of the distillation may be rectified and concentrated by undergoing a second distillation over a quantity of sifted ashes, the phlegm being left behind. The addition of the ashes, in this case, as well as of the chalk and pot-ash to the sal ammoniac, is founded upon this circumstance, viz. that the volatile alkali is detached from its different combinations by such bodies as have an affinity with the marine acid in the sal ammoniac, and with the phosphoric acid in the urine.

The artificial composition, or generation of this salt, by many chemists supposed to be possible, is as impossible as that of the other two alkalies. The facts which they adduce in proof of this have not been judged with due discernment, and merely go to prove the expulsion of a latent volatile alkali. To this head I refer the treatment of divers expressed, ethereal, and empyreumatic oils, as also of various acids, e. g. the nitrous, acetous, and myrmecic, as also of the mineral salts, and even of the pure acids themselves, with lime, ashes, or fixed alkali. If by these means then it can be separated from the pure acids, the appearance of it must necessarily proceed from no other cause, when a solution of a metal in these acids being evaporated to dryness, upon the addition of lime or * fixed alkali, yields a portion of volatile alkali.

With

* M. *Berthollet* has discovered, that whenever inflammable gas can unite with mephitis, the chief constituent part of the nitrous acid, there is a generation of volatile alkali. Thus this substance

With the ſimple ſalts hitherto deſcribed, various kinds of ſaline combinations may be effected in different ways, either by uniting theſe ſalts with each other, or with different earths, or with metals, or with combuſtible bodies. The combinations of the three firſt ſorts are called *neutral ſalts*; of which again the former are termed *perfect*, and the latter *earthy* or *metallic neutral ſalts*. The combinations of ſaline matters with combuſtible ſubſtances cannot be properly referred to the neutral ſalts, neither can any general appellation be given them, unleſs perhaps they may be called *phlogiſtic ſaline combinations*. In this caſe they may be conſidered as appendages to the neutral ſalts*.

By *perfect neutral ſalts*, ſuch combinations only muſt be underſtood, as (with excluſion of earths and metals) are compounded of acids and alkaline ſalts, perfectly ſaturated on both ſides; whether one acid only be united with one alkali, or more than one of either ſort be combined together. This kind muſt not poſſeſs a redundancy either of acid or of alkali, and moreover neither efferveſce with an acid, nor with an alkali. If notwithſtanding an ebullition ſhould enſue with the concentrated vitriolic acid in neutral ſalts prepared with weaker acids, in ſuch caſes this ebullition is owing to the expulſion of theſe acids by one more powerful †. They likewiſe do not produce the leaſt alteration in the blue tinctures of different flowers. Moſt of theſe ſalts concrete in cryſtals, each of which has its peculiar figure.

In every preparation of a neutral ſalt, an efferveſcence is obſerved during the mixture of the acid with the alkaline ſalt, which continues till the mixture has attained the point of ſaturation. This phenomenon was formerly conſidered as the reſult of a conflict between the two ſalts, as they were ſuppoſed to be contrary to

ſubſtance is generated from a mixture of nitrous gas, iron and water; and alſo from tin precipitated ſpontaneouſly from nitrous acid and ſaturated with with fixed alkali. Vid. *Mem. de l'Acad. des* Sc. 1785.

Our author, to whom theſe important diſcoveries were unknown, has, with his uſual ſagacity, increaſed the catalogue of theſe ſubſtances, though, inſtead of pre-exiſting in them, we have every reaſon to ſuppoſe the volatile alkali generated here. [E]

* The former kind of neutral ſalts are alſo called *ſaline neutral ſalts*, in order to ſhew that they conſiſt intirely of ſaline particles; or ſimply, *neutral ſalts*, becauſe they are neither of an acid nor of an alkaline nature. [A]

M. *Wiegleb* with moſt German writers, beſtows upon the ſalts mentioned above in the Text, the general appellation of *Middle Salts*, (*Sales Medii*), from which he diſcriminates thoſe which are compoſed of an acid and an alkali, by the name of *neutral* ſalts. As in our language we have not yet adopted the term of middle ſalts, it may perhaps be as well to call them all (as we have done here) neutral ſalts in a general way, and to particularize the perfect combinations by the denomination of (Sales Salſi or) *Saline Salts*. [E]

† This is always the caſe with the aerial acid, and that not only on the addition of the vitriolic, but of almoſt every other acid. [E]

each other. This enmity cannot however be proved, but it rather appears, that these two kinds of salts produce this appearance, only because they penetrate each other too much; so that this effect rather proceeds from their mutual strong attraction, inclination, or affinity. Now as, on being mixed together, they unite so intimately with each other, they of course expel all other substances in proportion to the opposition these offer to their union. These substances are the aerial acid, the matter of fire, and phlogiston *, of which the former in particular is the principal cause of all effervescences of this kind.

From what has been said it appears, that in every perfect neutral salt, both the different primary kinds of salts, viz. acid and alkali, are required. But as there is such a variety of acids, which are either of a mineral, vegetable, or an animal nature, and as there are three different kinds of alkaline salts, it is easy to conceive, that upon the whole, a great number of neutral salts, but yet from each acid no more than three particular sorts, can be produced, which are constantly distinguishable from each other according to the diversity of the acid and the alkali of which they are composed, and ought also to be marked by distinct appellations.

The *vitriolic* acid, according to the different state it is in, and the different nature of the alkali, forms different neutral salts. Pure vitriolic acid, with each of the fixed alkalies, yields fixed neutral salts, of a bitterish taste; but with the volatile alkali, it produces a peculiar kind of sal ammoniac.

From the combination of the vitriolic acid with the mineral alkali, arises *Glauber's salt*, (Sal mirabile Glauberi †). This in a red heat undergoes the igneous fusion, is easily dissolved in water, and concretes in crystals of the form of a flattened hexagonal prism, with dihedral extremities, which take up a great quantity of water, but lose it again in the open air, and fall into a powder, which weighs but half as much as the salt did before. To the large portion of water contained in its crystals, it is owing that this salt first melts in a very low degree of heat, then grows hard, and at length, but not before, passes over to the igneous fusion. The same salt may be prepared in a direct manner from the mineral alkali and the vitriolic acid; but this way is by far too expensive, and consequently is not used. 100 parts of mineral alkali, urged with a red heat, lose

* This matter of fire is merely hypothetical, neither does even phlogiston alone seem to have any influence in causing effervescence in bodies; but, when united with the base of nitrous acid in nitrous gas, or with hydrophloge in inflammable gas, it volatilizes them, and thus enables them to produce an effervescence in the mixture, when they are separated from it by the action of a stronger acid. In short, the only substances which seem capable of causing effervescence in mixtures, appear to be aerial acid, mephitis, pure air, nit ous and inflammable gas. [E]

† Or *Natrous Vitriol.*

in

in ſuch ſaturation 32 parts of aerial acid, and yield 120 parts of Glauber's ſalt, likewiſe expoſed to a red heat; which conſequently conſiſt of 68 parts of mineral alkali deprived of its fixed air, and of 52 parts of concentrated vitriolic acid. 100 parts of the cryſtallized ſalt contain nearly 50 parts of water of cryſtallization. The moſt common practice is, to endeavour to obtain it indirectly, and as an adventitious product, from the caput mortuum remaining in the diſtilling veſſel, after the expulſion of the marine acid from common ſalt, by the acid of vitriol; for which purpoſe, nothing more is requiſite than to diſſolve the reſiduum, filter it, and ſuffer it to cryſtallize. If the operator has it not in view to ſave the marine acid, the mixture of the oil of vitriol with the common ſalt may be made under a chimney that has a good draught, in a crucible, which is afterwards to be ſet upon the fire, and kept there till all the marine acid be expelled up the chimney. In the ſame manner this ſalt is obtained in thoſe inſtances in which alum or common vitriol has been employed for the expulſion of the marine acid; as likewiſe from the lixivia remaining after the ſeparation of the ſedative ſalt from borax by vitriolic acid; in the precipitation of alum, ſal catharticus, and divers vitriols, by a pure ſalt of ſoda: and in like manner the author of "Chemical Experiments by a Society in the Mines" obtained it from mere common ſalt and vitriol of copper, by a long continued gentle heat. Nature alſo preſents us with this neutral ſalt in many places. *Model* ſays, that there are whole tracts of country in *Siberia*, where ſeveral tons of Glauber's ſalt are elixated from the mere earth, and boiled down yearly. The ſea-water, likewiſe, and ſeveral brine-ſprings and mineral waters, contain it, of which we have inſtances in the *Carlſbad* ſalt, and the *Frederick's* ſalt at *Erlang*. In the cryſtallization of this ſalt we muſt not, as in other neutral ſalts, wait for the appearance of a pellicle upon its ſurface, for it does not form one. The point of cryſtallization of the ſaline lixivium muſt therefore be aſcertained, by ſetting apart a ſmall portion in a ſaucer to cool ſpeedily, or by letting fall a few drops of it on a piece of cold iron. One part of Glauber's ſalt, which from being expoſed to warmth has fallen to powder, when mixed with two or three parts of water, forms inſtantly a maſs like ice.

By the combination of the vitriolic acid with vegetable alkali, is generated *vitriolated Tartar**. This is leſs ſoluble in water than many other neutral ſalts; hence it cryſtallizes very rapidly in this fluid, and forms hexäedral cryſtals, with hexäedral apices. They take up very little water in their cryſtallization, and for this reaſon do not undergo any change when expoſed to the air; and in fire, are fuſed only in the moſt intenſe heat. This firſt compoſition of vitriolated tartar takes place when a diluted acid of

* Or rather *Spodic Vitriol.*

vitriol

vitriol is poured upon a ſolution of purified vegetable alkali in water, till no farther effervefcence is to be perceived. Upon which the liquor is to be evaporated till a pellicle appears on its ſurface, then filtered, and put by for ſeveral days in a cool place to cryſtallize. 100 parts of purified alkali which has been urged with a red heat, loſes by ſaturation with vitriolic acid 34 parts of aerial acid, and yields 105 parts of neutral ſalt in like manner expoſed to a red heat, which ſalt conſequently contains 66 parts of alkali deprived of its fixed air, and 39 parts of highly concentrated vitriolic acid. In the cryſtallization, 100 parts ſcarcely abſorbs from ſix to eight parts of water. Each ounce of purified vegetable alkali takes about five drachms of concentrated vitriolic acid to ſaturate it. According to *Tachenius*'s recipe, inſtead of mere vitriolic acid, vitriol is diſſolved in hot water and filtered, to which a ſolution of pot-aſh in like manner made hot, is added by degrees, till neither effervefcence, nor any farther precipitation, nor a vitriolic taſte are any longer perceptible. Here the acid of the vitriol unites with the alkali; and the earth of iron is ſet at liberty and precipitated. This ſalt is obtained under ſimilar circumſtances, by pouring a ſolution of the alkaline ſalt into a ſolution of alum, or of Epſom ſalt; till the mixture ceaſes to be rendered turbid by it: as alſo by mixing ſulphur with the alkali, and roaſting the mixture for a long time till it acquires a red heat; or by boiling gyps with the alkali, or, which is ſtill better, calcining them together for a ſhort time. It may alſo be procured in great abundance from the reſiduum of the pot-aſh, which is left undiſſolved after pure alkali has been extracted from it, with a ſmall portion of cold water, by diſſolving it in a ſufficient quantity of boiling water, filtering and cryſtallizing it. The moſt conſiderable quantity of this ſalt, is in ſeveral other operations obtained adventitiouſly and indirectly. Hither may be referred the reſiduum of the diſtillation of the nitrous acid, in which either vitriolic acid, or vitriol itſelf, or alum has been employed. The ſalt obtained on this occaſion, has in former times, when no proper judgment could be formed of its origin, had various names impoſed upon it; ſuch as *Arcanum duplicatum*, *ſal ſapientiæ*, *panacea Holſatica*, & *nitrum vitriolatum*. But in fact, all ſalts which ariſe from the combination of the vitriolic acid with vegetable alkali, on what occaſion ſoever, are, after undergoing a previous purification from all extraneous ſalts, and earthy or metallic particles, in every reſpect ſimilar to each other.

From the combination of the vitriolic acid with volatile alkali, ariſes *vitriolic*, *ammoniac* or *Glauber's ſecret ſal ammoniac*, (ſal ammoniacum ſecretum



Glauberi).

Glauberi)*. This is not so easily sublimed as the common sal ammoniac, but its composition is destroyed again merely by fire; the volatile alkali escapes, and the vitriolic acid remains behind in the glass †. It is obtained by merely mixing volatile alkali with vitriolic acid to the point of saturation; besides this, it is also generated, when a solution of vitriol of iron, alum, or Epsom salt is precipitated with volatile alkali, or when the marine acid has been expelled from sal ammoniac by concentrated vitriolic acid. And as most crude clays contain volatile alkali, this sal ammoniac will be adventitiously produced when these earths are treated in a brisk fire with vitriolic acid in close vessels. It forms pyramidal crystals. It is also found native in the neighbourhood of Volcanos. No particular use of this salt is known.

From the abovementioned neutral salts obtained from the more fixed vitriolic acid, those which are prepared from the more *volatile*, or *sulphureous vitriolic acid* with the three alkalies, are distinguished partly by a volatile sulphureous smell, and partly by the following criterion: that this acid, on account of the phlogiston combined with it, may be easily expelled from them again by other weaker acids. And as the mere sulphureous acid loses its phlogiston when exposed to the air, and becomes similar to the fixed acid: the same change also takes place with respect to the neutral salts produced from it: that is, when they are exposed to the air for a certain time, they lose their peculiar property, and assume the nature of neutral salts which have been prepared with the more fixed acid.

If this acid be united with the mineral alkali, it produces salt, known by the appellation of *sulphureous salt of soda*, (alkali fixum minerale sulphuratum ‡). This combination may be effected in a direct manner with the sulphureous acid of vitriol and salt of soda; or indirectly, when either of these two salts has already dissolved some other body, which is afterwards separated by the other salt: likewise when cubic nitre is mixed with half its quantity of sulphur, and poured into a red-hot crucible; the salt remaining after this operation is dissolved, filtered and crystallized. Of this salt no particular use is known: and indeed it is seldom produced indirectly in the course of other operations.

* More properly called, *Ammoniacal Vitriol*. [E]

† Vid. *Weber* on the Nature and Properties of Lime, *Berlin* 1728, pag. 8. *Langmayer*, Supplem. in defens. *Wells*, Vindob. 1778, pag. 289, seq.

‡ Or better, *Natrous Sulphurocrate*. [E]

More generally known than this is the *sulphurated salt of tartar*, which on account of its more volatile vitriolic acid, is sometimes called *volatile vitriolated tartar*, and is more frequently to be met with than the former. It is also called *tartarus sulphuratus*, *sal neutrum sulphuris*, *tartarus vitriolatus volatilis*, but more properly, *alkali fixum vegetabile sulphuratum* *. As to its form and other properties, it very nearly resembles the real vitriolated salt of tartar, those phenomena excepted, which depend on the volatility of the acid. If however it be exposed to the air for a considerable time, every difference vanishes by degrees, together with the phlogiston. As this salt is produced in various ways, and as our predecessors could not possibly at that early period of Chemical Science perceive the identity we speak of, hence arose the several appellations which have been bestowed upon it. *Stahl* produced this salt by an immediate combination of the volatile sulphureous acid with the vegetable alkali, by collecting the vapor of burning sulphur with linen rags, which he suspended over it, after steeping them in a solution of vegetable alkali; he then elixated them with warm water, and suffered the liquor to evaporate, and crystallize. For this reason this salt is sometimes also called *sal sulphureum Stahlii*. Liquid sulphureous acid of vitriol is, it is true, seldom directly and purposely united with vegetable alkali, by which means, however, the very same salt would be produced. This salt is also generated by exposing liver of sulphur, prepared with two parts of alkali and one part of sulphur, to a low red heat, and dissolving in water the salt remaining after this operation, and afterwards filtering and setting it by to crystallize. Perfectly like this is the *polychrest salt* of *Glaser*, or of *Lemery*, which is prepared from nitre mixed with half or an equal quantity of sulphur, by projecting the mixture by little and little into a red-hot crucible, and reducing the mass that remains after this operation into its proper form, by solution, filtration, and crystallization. Hence it is easy to conceive, that even in making the salt, known by the name of *sal prunel*, there must be generated a certain portion of this sulphureous neutral salt, which however is concealed under the greater bulk of the nitre that has not been decomposed. This latter salt is produced by pouring gradually on pure nitre in fusion, about a twelfth or a sixteenth part of sulphur, and afterwards forming the salt, while it is yet fluid, into small cakes.

* More properly still, *Sulphurocratium Spodicum*, or Spodic Sulphurocrate. [E]

Laſtly, from the ſulphureous or volatile vitriolic acid, and the volatile alkali, ariſes the *ſulphureous ammoniac* * (ſal ammoniacum ſulphuratum, tartarus vitriolatus Stahlii) in all thoſe caſes in which they can enter into union with each other. It is not probable indeed that they will often be combined together with a view of obtaining this ſalt, excepting indirectly in ſome caſes, as for inſtance, when a ſulphureous naphtha is to be corrected by the ſpirit of ſal-ammoniac. Even this ſalt which is of ſo peculiar a quality, is likewiſe found native in ſeveral places in the vicinity of volcanos, and accordingly occurs in a ſaline compound found near *Salfatara,* and deſcribed by M. *Sage.* This ſulphureous ſal ammoniac alſo becomes very like the ſal ammoniac of Glauber, if it be expoſed to the air for a certain time.

The *nitrous* acid combined with the three different alkaline ſalts, generates alſo three different kinds of neutral ſalts; which are diſtinguiſhed very evidently from all others, by the circumſtance of detonating in the fire, when united with inflammable ſubſtances. For the detonation of the neutral ſalts compounded of the two fixed alkalies with this acid, this addition together with a red heat is requiſite, which however is not neceſſary for the neutral ſalt compounded of the volatile alkali, as it already contains phlogiſton in its compoſition. They are alſo farther diſcriminated by a ſenſation of coolneſs to the taſte, and by the difference of their external form from that of other neutral ſalts; as they are alſo manifeſtly diverſified from each other, according to the different nature of the alkaline ſalt employed in their production.

From the combination of this acid with the mineral alkali, ariſes *cubic* or *quadrangular nitre* †, (nitrum cubicum) ſo called from the form of its cryſtals. It may be obtained in ſeveral ways. Firſt; By mixing nitrous acid directly with ſalt of ſoda to the point of ſaturation. Or ſecondly; by diſengaging the marine acid from common ſalt, agreeable to *Marggraf's* preſcription, by double the quantity of ſmoaking ſpirit of nitre, and diſſolving the reſiduum in water, and afterwards filtering, evaporating, and cryſtallizing it. Or thirdly; by precipitating different ſolutions of earthy or metallic ſubſtances in nitrous acid, by a ſolution of ſoda. Or fourthly; by the ſeparating ſedative ſalt from borax, by means of nitrous acid. A hundred parts of mineral alkali, that has been expoſed to a red heat, loſe, in their ſaturation with nitrous acid, 36 parts of aerial acid, and yield 120 parts of cubic nitre, which has likewiſe been urged with a red

* *Ammoniacal Sulphurocrate* (Sulphurocratium ammoniacum). [E]

† Alſo, from a more accurate conſideration of its cryſtals, termed, *Rhomboidal Nitre.*---More properly ſtill, *Natrous Nitre.* [E]

heat,

heat, and which confequently confifts of 68 parts of mineral alkali deprived of its fixed air, and of 52 parts of concentrated nitrous acid. In the cryftallization, nearly 25 parts of water are added. In the Eaft, where the earth contains a greater quantity of mineral alkali, it muft of courfe happen, that the nitrous acid which has been generated in this earth, partly enters into combination with the alkali, and that thus native quadrangular nitre may be found in it. Perhaps even in *Germany* it is not fo rare as it is fuppofed to be; fince *Marggraf* affures us, that he once received fome nitre from a falt-petre manufactory at *Naumburg*, which after it had formed the long prifmatic cryftals, yielded quadrangular nitre. It has, like common nitre, a cool tafte, like it liquefies in the fire, and detonates quickly on the addition of combuftible matter, without any decrepitation, and with a yellow colour, whichi n common nitre, in the like cafes, is never obferved. In this operation, if the nitre was pure, it leaves the mineral alkali free and uncombined behind. A pure folution of it in diftilled water, does not precipitate folutions of filver, lead, or mercury, in the nitrous acid, which feems to indicate the remains of a latent marine acid.

From the union of this acid with the vegetable alkali, arifes *common nitre* (nitrum vulgare). It is diftinguifhed from the preceding, by the hexaedral prifmatic cryftals, with hexaedral apices, which it forms in its cryftallization. Hence it is alfo called *prifmatic, nitre,* (nitrum prifmaticum). This falt does not appear to have been known above 800 or 1000 years, and even to have been indebted for its origin to the alchemifts. Though the name of falt-petre, *nitrum, fal petræ,* be found in authors yet more ancient, it is neverlefs very certain from the properties which they afcribe to it, that by this they meant quite a different falt. The alchemifts, who afcribed the generation of metals to the immediate influence of the ftars upon the earth, fought to profit by this imaginary power: they therefore expofed different earths to the air, and to the rays of the fun, expecting to collect in them the omnipotent fpirit of the univerfe. This has probably given occafion to the difcovery of our modern falt-petre in the earth.

When the acid, which has been feparated from nitre, is by art combined to the point of faturation with vegetable alkali, in like manner uncombined, and is cryftallized; it is called *regenerated nitre,* (Nitrum regeneratum); a falt, which is perfectly the fame with the falt-petre obtained from the earth, from the compofition of which therefore the proper conftituent parts of the other may be incontrovertibly known. But if yet more nitrous

acid

acid be added, ſo as to exceed the point of ſaturation, and the ſalt be evaporated to dryneſs without being cryſtallized, that ſalt is obtained, which the ancient phyſicians called *Nitrum nitratum*. A regenerated nitre may alſo be obtained by diſſolving in nitrous acid the arcanum duplicatum, or a vitriolated tartar produced in any other method, and ſetting it by to cryſtallize; or elſe by precipitating earths or metals that are diſſolved in the nitrous acid by means of vegetable alkali. With regard to the proportion of theſe conſtituent parts, it is worthy of obſervation, that a hundred parts of alkali that has been expoſed to a red heat, loſe 32 parts of aerial acid, on being ſaturated with nitrous acid, and yield 112 parts of nitre in like manner urged with a red heat; which conſequently conſiſt of 68 parts of alkali deprived of its fixed air, and 54 parts of concentrated nitrous acid, and, in cryſtallizing take up about 20 parts more of water.

As this ſalt is at preſent uſed on a great variety of occaſions, and is therefore become indiſpenſibly neceſſary, all poſſible means are employed for obtaining it from nature in the greateſt quantity, and in the moſt advantageous way. For this purpoſe, *ſalt-petre manufactories* have been eſtabliſhed in which the following proceſs is generally adopted; viz. all kinds of porous earth, ſuch as mud from the bottoms of ponds and other pieces of water, filth from the ſtreets, rubbiſh of buildings, chalky loam, ſoap-boilers aſhes, ſtraw-aſhes and the elixated aſhes of pot-aſh manufactories, are mixed together, and piled up in looſe, pyramidal heaps under a ſpacious and lofty ſhed, which muſt be covered with a wooden or even with a thatched roof only; and the reſult left to the operation of nature. Theſe heaps ought to lie in this manner ſeveral years, and during the whole time to be kept continually moiſt either with urine, and the drainings of dunghills, or with water only, and likewiſe frequently turned and made up again into their former ſhape. Walls may alſo be made of this compoſition higher and thicker than the heaps here ſpoken of, which walls however ought likewiſe to be kept under roofs like the heaps, by way of ſheltering them from the rain, and the direct rays of the ſun. A good draught of air however is the chief object, and indiſpenſibly requiſite in every production of ſalt-petre, becauſe the air by its actual acceſſion performs theprincipal part in the proceſs. Ditches and ſalt-petre vaults are of no manner of uſe, as many have experienced to their coſt. By means of this apparatus the nitrous acid is generated in the humid and light porous earth, and that merely on its ſurface, by the air which is continually inſinuating itſelf into this earth, and by the matter of fire, with which the air is combined.

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We muſt not imagine however that the acid of nitre is merely attracted from the air by the earth; for hence it would follow, that this acid is actually contained ready-formed in the air, an aſſertion, which cannot by any means be proved: for M. *Marggraf*, in a great quantity of rain water, found very ſlight veſtiges of this acid. Neither is there the leaſt foundation for the notion, with which many have buoyed themſelves up, that common ſalt may be converted into ſalt-petre by means of a ſpontaneous decompoſition in conſequence of expoſure to the air. Indeed, it is much more probable, that the volatile alkali, which is extricated by means of putrefaction from the ſubſtances uſed in this proceſs, and which is alſo found in the mere earths alone, enters the compoſition of the nitrous acid, united with a ſtill greater quantity of the matter of fire*.

Beſides this artificial method of preparing it, nature produces this ſalt in divers places, though for the moſt part in an imperfect ſtate. It is ſometimes found cryſtallized upon damp walls made of lime or loam, where animal and vegetable ſubſtances of all kinds occur, in the laſt ſtage of putrefaction, mixed with calcareous earth. In theſe places it is diſſolved by the rain, and introduced into the ſubſtance of vegetables, and diffuſed in the waters of rivers.

The greateſt part of the nitre thus generated in the earth, is not yet a perfect neutral ſalt, as it ought to be; but commonly conſiſts of the nitrous acid combined with various ſoluble earths. Hence it is, that in general when the ſalt-petre earths, after having been expoſed for a ſufficient time to the action of the air, are elixated with water, and the liquor is boiled and ſuffered to cryſtallize, no perfect nitre, or at leaſt but a ſmall quantity of it, is obtained. The reaſon is this, that the ſalt-petre earth never contains as much fixed alkali as the newly-generated acid requires in order to be ſeparated from the earth, and combine with the former, ſo as to form a perfect neutral ſalt. Formerly it was abſolutely denied, that a perfect nitre was any where to be found in nature; becauſe the exiſtence of the alkaline ſalt, one of its neceſſary conſtituent parts, was not yet known. At preſent however there is not the leaſt doubt, but that a perfect nitre may alſo be found, and indeed actually does occur in nature. The nitre, which is collected in the Indies, and known by the denomination of *ſalt-petre ſweepings*, from its being ſwept together there from the ſurface of the earth; likewiſe a kind of a grey rock, deſcribed by *Wallerius*, which after a ſpontaneous

* We now know that nitrous acid and volatile alkali both contain the ſame principle, viz. mephitis, which in nitrous acid is combined with air and water; and in volatile alkali with inflammable gas; i. e. the baſe of water united with phlogiſton. [E]

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decompoſition, produced by mere elixation, a perfect nitre; as alſo the aſſertion of *Bowles*, that all the nitre in Spain is produced by a mere elixation of the earth without any addition either of aſhes or of an alkaline ſalt: all theſe, together with many more obſervations and experiments made by individuals, plainly prove that a perfect nitre certainly occurs ready formed in nature. In thoſe countries, however, where the earth does not contain the fixed alkali in great abundance, the nitrous earth ought either to be mixed immediately before the elixation with a ſufficient quantity of wood aſhes, or elſe the nitrous acid and the aſhes ſhould be elixated each by themſelves in ſeparate veſſels, and the leys afterwards mixed together. The effect produced by the alkaline ſalt in this operation is, that the earths united with the nitrous acid are ſeparated from it, and that the pure acid alone forms with it a perfect neutral ſalt. Hence it is eaſy to infer, that a certain quantity of alkali is requiſite for this purpoſe, and that it is by no means indifferent what quantity of aſhes is employed. When the nitrous lixivium, which is to be boiled, ceaſes to be rendered turbid by the addition of a ſtrong ley made of wood-aſhes, whilſt it ſtands on the fire, it may be conſidered as a ſign, that a ſufficient quantity of alkali has now been added, and the evaporation may be carried on ſlowly, till the lixivium, which muſt be kept continually ſkimmed, is condenſed to that degree, that part of it, on being poured out into a ſaucer, and ſet by in a cool place, will totally concrete into cryſtals in a ſhort time; upon which it is poured into appropriated wooden veſſels, for the purpoſe of cryſtallization*.

The ſalt, which in this method cryſtallizes firſt, is called *crude* or *impure nitre*, and commonly contains various neutral ſalts beſides, excluſively of the greaſy and mucous matter, which has been elixated along with it from the earth: conſequently it ought to be conſidered as a multifariouſly compounded neutral ſalt. For excluſively of the true genuine nitre, we find in it a portion of common ſalt, digeſtive ſalt, nitrous ammoniac, ſometimes cubic nitre, and various other earthy ſalts beſides. On account of this quality it ought to be farther refined, before it is fit for ſale. This is done by diſſolving it once more in water, or in many caſes in a ley made of wood-aſhes, ſtraining it off clear, boiling it again ſlowly, and cryſtallizing it a ſecond time. On occaſion of this purifica-

* A circumſtantial account of the whole proceſs of this manufactory is to be found in *Simon's* Art of making Sal-petre. *Dreſden*, 1778. Alſo in the *Memoires ſur la formation de Nitre*, publiſhed in 1776, by the French academy. On this ſubject likewiſe may be conſulted *J. A. Weber's* Treatiſe on Salt-petre, and the Method of producing it. *Tubingen*, 1779.

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tion, the lixivium ought not to be boiled down ſo low as it was at firſt, in order that the extraneous ſalts be not made to cryſtallize again with the nitre as they did before. And by this means is obtained the *refined ſalt-petre*, in the ſtate in which it is commonly ſet up to ſale.

But as this ſalt-petre is ſtill not purified to ſuch a degree of perfection, as not to contain ſome neutral ſalts foreign to its compoſition, it ought, as well for medical as more particularly for chemical uſes, to be diſſolved and cryſtallized ſeveral times more; at the ſame time too, care muſt be taken that the firſt cryſtals only be employed for the purpoſe of a farther purification; the ſubſequent lixivia, on the other hand, as long as they continue to yield genuine ſalt-petre, ſhould be cryſtallized by themſelves and ſet apart for particular uſes. All other artificial methods of purifying this ſalt, whether with vinegar or urine, or whatever elſe a fertile imagination may ſuggeſt for this purpoſe, are really of no uſe.

Now, accordingly as the proceſs for preparing the firſt lixivium from the ſalt-petre earths has been conducted, and in proportion to the quantity in which the nitrous acid generated in theſe earths, has been ſaturated with alkali, there will remain, after the firſt cryſtallization, more or leſs of a lixivium which is not farther cryſtallizable. This lixivium is called the *Mother-water*; and according to theſe different circumſtances will be of a quite different nature. In the proceſs followed by the ordinary manufacturers of ſalt-petre, who commonly, to their own great diſadvantage, do not uſe as much wood-aſhes for their ſalt-petre-ley as they ought to do, the mother-water ſtill contains a pretty conſiderable portion of nitrous acid, ſaturated with magneſia and calcareous earth: but of an unſaturated acid there is not the leaſt particle to be found in it. Now, in this caſe, in order to avoid loſing the nitrous acid, the lixivium may, it is true, be poured back upon the ſalt-petre earth, which has not yet been elixated; but it would be ſtill more advantageous to work it over again, with the addition of more wood-aſhes, in order to convert it into ſalt-petre. Beſides this, it is generally evaporated to dryneſs, and urged with a red heat, by which means the nitrous acid ſtill remaining in it is, in a very unthrifty manner, propelled into the air. The calcined maſs is then elixated with water, the fineſt particles of the earth decanted, ſeparated by filtration, and dried; and thus is obtained the *magneſia of nitre*; which however ſtill contains a ſmall portion of calcareous earth, and may be known by its being perfectly ſoluble in weak vitriolic acid. But if the proceſs has been

managed more ſkilfully at the firſt outſet, and the nitrous lixivium has been ſufficiently ſaturated with alkali, the mother-water remaining after the operation will be of a very different nature; it will yield little or no magneſia, it will likewiſe meaſure leſs, and will conſiſt merely of common and digeſtive ſalt with ſome viſcid matter. And now, even in this caſe, it would be more adviſeable to throw it away rather than ſpoil any freſh ſalt-petre earth with it. The magneſia juſt mentioned has been known only ſince the beginning of this century, and was firſt diſcovered at Rome.

Perfect purified nitre ſhould conſiſt of fine, tranſparent, colourleſs cryſtals of a priſmatic form; it ſhould be cool to the taſte, melt eaſily in the fire, and, when placed upon live coals, detonate briſkly. Various pharmaceutic preparations are compoſed of it. *Nitre-cakes* (Nitrum tabulatum) are nothing elſe than melted nitre, which, by means of an inſtrument made for the purpoſe, is divided into ſingle drops on a copper-plate, upon which they inſtantly grow hard, and retain the form they have acquired, and from which they derive their name. In the preparation of the *Clyſſus of Nitre*, which was uſed in former times, and for the production of which a certain quantity of nitre is mixed with twice its weight of powdered charcoal, and put by little and little into a tubulated retort, with a large receiver, the nitre is deſtroyed to no manner of purpoſe. In this operation, the nitrous acid is entirely deſtroyed* by the phlogiſton of the coals; and hence the liquor, collected in the courſe of it, does not by any means conſiſt of nitrous acid, but on the contrary has but little taſte, and contains merely the volatile alkali, which is now releaſed from the compoſition of the nitrous acid, and ſet at liberty again†. In the caput mortuum is found the fixed alkali of the nitre, which our

* We have frequently followed the author in ſpeaking of the *deſtruction* of a ſubſtance, more for the ſake of varying the phraſe than from our conviction of the propriety of the term as it is there applied. The proper idea in all theſe caſes is *decompoſition*; for, in fact, nothing can ever be deſtroyed in nature. To the chemiſt indeed, whoſe whole occupation is compoſition and decompoſition, this truth is particularly evident.

In the above-mentioned operation, the nitrous acid is decompoſed in its two conſtituent parts, and is ſo far from being deſtroyed, that both theſe parts, the mephitis and the pure air, are very eaſily found again, upon making due ſearch for them, in the veſſels in which the ſeparation is performed. [E]

† There is no volatile alkali in the compoſition of the nitrous acid: but the volatile alkali obtained in this operation proceeds from the fixed alkaline baſis of the nitre volatilized by heat, or

our good predeceſſors, through ignorance, uſed to call *fixed nitre (nitrum fixum)*. No real chemiſt will in theſe times think about making ſuch uſeleſs decompoſitions, by which he would only obtain certain products at a much higher rate, and of a ſtill worſe quality, than he might have in a ſhorter way and with leſs trouble. The alkali here obtained is not a pure alkali, but ſtill contains a ſmall portion of nitre undeſtroyed, and ſome phlogiſticated nitrous acid. The alkali, which is obtained in the abovedeſcribed method, was called by *Glauber*, after it had deliqueſced of itſelf by expoſure to a moiſt air, *Alkaheſt (Alkaheſt Glauberi*, or *Liquor Nitri fixi)*. The alkalization of nitre may be effected alſo in another manner in an open crucible by the addition of coals. The alkalization of it by a naked fire proceeds from the action of the alkali upon the earths, by which the acid is expelled. As to M. *Beaumé*'s pretended total volatilization of nitre, I will not take upon me to anſwer for it; ſince it is more probable, that this ſalt pervaded the veſſel; as all nitre, that is melted for a long time over the fire, uſually does.

Volatile alkali combined with nitrous acid produces a ſalt, called *inflammable nitre*, which is alſo termed *ammoniacal nitre*, or *nitrous ammoniac*, (nitrum flammans, ſal ammoniacum nitroſum). This ſalt is produced by ſaturating a ſolution of volatile alkali in water with nitrous acid, and after filtering the lixivium, evaporating it to dryneſs. According to *Bergman*, 100 parts of pure volatile alkali take 132 parts of nitrous acid to ſaturate it completely*. This combination alſo takes place in a more indirect manner and on occaſion of other operations and proceſſes. When, for inſtance, to common ſal ammoniac thrice its quantity is added of ſtrong nitrous acid, and the whole is diſtilled to dryneſs: and in like manner, when various earthy or metallic bodies, after being diſſolved in nitrous acid, are precipitated from it by volatile alkali; in which caſe alſo the ſaline liquor contains the nitrous ammoniac. It is diſtinguiſhed by the following properties: that though it contretes in priſmatic cryſtals, yet theſe eaſily deliqueſce when expoſed to the air, eſpecially when placed in a warm ſituation. This ſalt has likewiſe a remarkably acid taſte. It is alſo partly ſoluble in ſpirit of wine; and when deprived of all its humidity by the action of a tole-

or poſſibly from the mephitis of the nitrous acid in combination with ſome inflammable gas contained in the charcoal. The gas produced here conſiſts for the moſt part (according to M. *de Fourcroy)* of aerial acid, mixed with a ſmall portion of inflammable gas and mephitis. [E]

* The alkalies and earths are termed *pure* by *Bergman*, when they are not combined with aerial acid, and conſequently are in what Dr. *Black* calls a cauſtic ſtate. [E]

rable brisk fire, it will detonate of itself without the addition of phlogiston, even before it acquires a red heat, because the volatile alkali itself contains phlogiston as one of its constituent parts. Upon the same principles likewise the following fact may be explained, viz. that the residuum of hartshorn shavings, from which nitrous acid had been drawn off by distillation, at length detonated. As to the assertion of *Kurella*, that by a gentle heat the whole of it will fly off, and totally disappear, at the same time that with a more intense heat it may be sublimed in close vessels; a fact which is also corroborated by *Bergman*, but contradicted by *Beaumé* and *Vogel*, the result of this experiment is so uncertain, as not to allow one to pronounce too positively concerning it. From what has been mentioned just before, at page 213, when speaking of crude salt-petre, it is evident, that a combination of this kind likewise takes place in the operations of nature.

The third mineral acid, viz. the *marine acid*, produces likewise different kinds of neutral salts, which are peculiar to itself, and of which such as are fixed, lose their water of crystallization with a crackling noise, when subjected to a moderate heat, and melt when exposed to a brisk fire.

Of this acid and mineral alkali, is composed the common culinary salt, (*sal commune, muria*). This salt is chiefly obtained from the great store-house of Nature, and that in three different ways; and is distinguishable itself from those of which we shall treat immediately after, and which are somewhat similar to it, by the shape of its crystals, which at the bottom of the liquor are formed of cubes composed of quadrilateral funnels, and on the surface concrete in the form of square hollow pyramids. It very easily attracts moisture from the air, and decrepitates in the fire, after which it fuses quietly, and in this operation, provided it be free from other impurities, loses little or none of its acid. It may in some measure be volatilized by air and phlogiston, and sublimed in the form of flowers by the action of fire.

As all the marine acid that is used, must in general be extracted from common salt, the neutral salt produced by mixing this acid with mineral alkali to the point of saturation, is called *regenerated common salt* (*sal commune regeneratum*). This combination is likewise in several instances made in an indirect manner, and on occasion of other processes, e. g. when volatile alkali is separated from sal ammoniac by means of the salt of soda; or when various earths and metals which have been dissolved in the marine acid, are precipitated by salt of soda; or in the case of sedative salt being separated from borax by the marine acid. A hundred parts of mineral alkali urged with a red heat, lose in their

saturation

faturation with marine acid, 34 parts of fixed air; from which are obtained after evaporation, 105 parts of a neutral falt in like manner urged with a red heat, which confequently confifts of 66 parts of mineral alkali deprived of its fixed air, and of 39 parts of concentrated marine acid: but during its cryftallization, abforbs nearly fix parts of water befides into its cryftals. It is not neceffary to attempt to compofe this falt by art, fince it is already found in great abundance in nature, where it is chiefly diftinguifhed by different degrees of its purity. In the earth, the fea, and in different lakes and fprings, it is met with in great quantities; more fparingly, but yet almoft every where in the earth, from whence it is transferred into vegetable and animal bodies, in a diffolved ftate. Every nation endeavours to procure it from Nature in large quantities, by fuch methods, as are found by experience to be the moft convenient; becaufe the ufe of it is very extenfive and indifpenfably neceffary.

*Sal Gem, (Sal gemmæ, muria Montana)* is obtained from the earth in a perfectly folid form, but in different degrees of purity. If it be pure and tranfparent, it may be imediately ufed, in the ftate in which it is found; but if it contain any impure earthy particles, it fhould be previoufly freed from them. In fome countries it is found in incredible quantities; and dug up, like metals, from the bowels of the earth. In this manner has this falt been dug out of the celebrated falt mines near *Bochnia* and *Wieliczka,* in *Poland* *, ever fince the middle of the 13th century, confequently thefe 500 years, in fuch

* Though the falt mines of *Wieliczka,* near *Cracow* in *Poland,* have long aftonifhed the philofopher and traveller, yet it deferves to be remarked, that the quantity of rock-falt obtained from the mines at *Northwich* is greatly fuperior to that obtained at *Cracow.* The Bifhop of *Llandaff* affirms that a fingle pit, into which he defcended, yielded at a medium, 4000 tons of falt in a year, which alone is about two thirds of that raifed in the Polifh mines. This rock-falt is never ufed upon our tables, in its crude ftate, as the Polifh rock-falt is; and though the pure tranfparent falt might be ufed with our food, without any danger, yet it is prohibited under a penalty of 40*s.* for every pound of rock-falt fo applied. It is partly purified in water, and a great part of it is fent coaftwife to *Liverpool,* and other places, where it is ufed either for ftrengthening brine-fprings or fea-water.

Befides the falt-mines here mentioned, where the common falt is found in a concrete ftate, under the name of rock-falt, there is at *Cordova,* in the province of *Catalonia* in *Spain,* a remarkable folid mountain of rock-falt; this mountain is between four and five hundred feet in height, and a league in circuit; its depth below the furface of the earth is not known. This mountain contains the rock-falt without the leaft admixture of any other matter. (Vid. l'Hiftoire Naturelle de l'Efpagne, p. 406). Dr. *Watfon's* Chemical Effays, Vol. II. [E]

amazing

amazing quantities, that ſometimes there have been 20,000 ton ready for ſale. In theſe mines, which are ſaid to reach to the depth of ſeveral hundred fathoms, 500 men are conſtantly employed.—The pure and tranſparent ſalt needs no other preparation than to be beaten to ſmall pieces, or ground in a mill. But that which is more impure, muſt be elutriated, purified, and boiled. That which is quite impure and full of ſmall ſtones, is ſold under the name of *Rock-ſalt*, and is applied to ordinary uſes; it may be likewiſe uſed for ſtrengthening weak and poor brine-ſprings.

The water of the ſea is doubtleſs poſſeſſed of a not much inferior ſtore of *common* or *ſea* ſalt. In warm countries that lie near the ſea, and are ſometimes inundated, this ſalt is found in the clifts of rocks, and pits, and other hollows, as alſo on the ſhores themſelves, in the form of a white dry ſubſtance, where it may be elixated out of the ſand that is caſt up on the ſhore, and may afterwards be boiled down. In the northern parts, the ſea-water is very little impregnated with ſalt, and therefore it would not pay the expences of boiling. In the ſouthern climes, however, the ſea contains much more ſalt, which therefore may be very conveniently extracted from it by coction; but it is a more common practice to collect the ſea-water in pits, at the time of high water, and ſo leave it to evaporate by the heat of the ſun. Theſe pits are lined either with boards, or elſe with brick-work; and their bottoms covered with clay, or plaiſter. The ſalt obtained in this way, is called *Bay-ſalt*, and is commonly exported to ſuch countries as have no ſalt of their own, but are not deficient with reſpect to the fuel neceſſary for boiling it. There it is again diſſolved, clarified, and deſpumated by the addition of different ſubſtances, ſuch as the white of eggs, whey, blood or yeaſt; and laſtly, refined by boiling it down, till it becomes a good uſeful white ſalt.

There is no difference between this ſalt and the *lake-ſalt* extracted from different lakes, excepting ſuch as may be occaſioned by the caſual intervention of ſome ſubſtances. In this reſpect the *Jeltonic* ſalt-water lake in the Ruſſian dominions near *Saratow* and *Dmitrewſk*, deſerves our attention. In the year 1748, when the Ruſſians firſt fetched ſalt from thence, the lake was almoſt ſolid with ſalt; and that to ſuch a degree, that they drove their heavy waggons over it, as over a frozen river, and broke up the ſalt. But ſince the year 1757, the water has encreaſed ſo much, that at this preſent time, it is nothing more than a lake very ſtrongly impregnated with ſalt. The *Jeltonic* lake-ſalt contains at the ſame time alum and Epſom-ſalt.

The salt of *brine-springs* differs from sea and lake-salt in no other way than as it is obtained from solitary sources of salt-water, usually called *brine-springs* *. When springs of this kind contain a store of salt sufficient to pay the expences of the fuel, they are directly boiled down in iron pans, and during the boiling, the impurities contained in them, are separated by the means already described. Those springs however which do not contain a quantity of salt sufficient to pay the cost of fuel, must be freed from their superfluous water, either by freezing or by the heat of the sun, or by *graduating*. These very useful edifices, called Graduating houses †, were invented in *Germany*, and the plan of the first, which was built at *Kotschau*, in the district of *Meerseburg*, in the year 1599, was laid down by a physician of this town (*Langensalza*) named *Matthew Meth*. By these expedients the brine-springs are evaporated till they are brought to a certain degree of strength, which is to be ascertained by means of an areometer, which degree however is not the same in all manufactories, and depends on the price of fuel in the countries where they are established. The mother-water that is left at the last, is not of the same quality in all brine-springs. Commonly it consists, 1. of a combination of the marine acid with magnesia: 2. of vitriolic acid and calcareous earth: 3. of the same acid and magnesia, i. e. of Epsom-salt: 4. of this acid and mineral alkali, consequently of Glauber's-salt: 5. of genuine sal ammoniac: and 6. of a portion of perfect common salt. The selenite contained in all brine-springs, is for the greatest part separated in the boiling down, or else in the graduating, in which latter process, it covers the thorns and other wooden materials, with a stony crust ‡. The slower the brine-spring is boiled down, and the purer it is, the larger will the crystals be, and the sharper their taste.

* The best of the *Barton* and *Northwich* brines contain about $\frac{1}{4}$ of salt. (Vid. *Lewis*'s Note to *Newman's* Chemistry, pag. 212). At *Middlewich*, there is said to be one salt-spring which is stronger than the rest. This spring yields a full fourth part of salt. (Phil. Trans. Vol. LIII). According to *Kircher's* account, there are some springs in *Burgundy* that yield $\frac{1}{4}$ part of white salt. (*Kircher's* Mund. Subt. Tom. II. cap. XI). These brines are saturated enough to be boiled down for the sake of the salt. Dr. *Watson* ibid. [E]

† Graduating houses, are buildings covered at the top, but open on the sides. The water of the springs is raised by pumps to the top of these buildings, and being let fall upon bundles of twigs or faggots, is divided into a shower, by which means its surface is increased, and the evaporation is promoted by the free current of air that passes through the open sides of the building. [E]

‡ The way how to employ the mother-water of brine-springs to the best advantage, is extremely well described in *Weber's* "Newly discovered Nature and Properties of Lime," *Berlin* 1778, pag. 166—237.

Marine

Marine acid united with common alkali, produces a ſalt not unlike the preceding, which is known by the name of *digeſtive ſalt*, or *febrifuge ſalt of Sylvius* (ſal digeſtum vel febrifugum Sylvii). By ſome too it is very improperly called *regenerated common ſalt*, (ſal commune regeneratum), and by others, ſtill more improperly, ſpiritus ſalis coagulatus. It is obtained by ſaturating a ſolution of vegetable fixed alkali with marine acid, till no farther effervеſcence enſues. A hundred parts of alkali urged with a red heat, loſt, on ſaturation with marine acid, 34 parts of aerial acid, from which after evaporation, and being a ſecond time ſubjected to a red heat, 104 parts of this neutral ſalt were obtained, which accordingly conſiſted of 66 parts of alkali deprived of its fixed air, and of 38 parts of concentrated marine acid. In cryſtallization it abſorbs about eight parts of water beſides. The ſame ſalt is obtained adventitiouſly from the reſiduum left after the preparation of ſpirit of ſal ammoniac by the addition of fixed alkali, and, in like manner, by the precipitation of different earths and metals diſſolved in the marine acid, by vegetable alkali: it occurs moreover in a great many vegetables, as alſo in common pot-aſh, in the lixivium of ſalt-petre earths, and in brine ſprings. It is diſtinguiſhed from the above-mentioned common ſalt, with regard to its external appearance, by the form of its cryſtals being perfectly cubical. On expoſure to the air, it becomes rather moiſt; and the taſte of it is ſomewhat ſharper than that of common ſalt *.

Laſtly, From the combination of the marine acid with volatile alkali, is obtained *ſal ammoniac* (ſal ammoniacum). In the firſt place, it may be produced from theſe its two conſtituent parts in their free and uncombined ſtate. Fifteen drachms of volatile alkali, on being ſaturated with marine acid, loſt five drachms and an half of aerial acid, from which, after perfect evaporation to dryneſs, were obtained 15 drachms and 2 ſcruples of ſal ammoniac, which conſequently

* M. *Berthollet* has produced a new ſalt by ſaturating the dephlogiſticated marine acid with vegetable alkali. To this ſalt he has given the name of *Muriat Oxygené de Potaſſe*. It might with leſs circumlocution, and perhaps with more propriety, be called *Epimuria ſpodica*, or ſpodic Epimuria. It has many of the properties of nitre. Boiling water diſſolves much more of it than cold water; and it cryſtallizes by cooling. When it melts on the tongue, it excites a ſlight ſenſation of cold: and it fuſes when placed upon live coals. Its cryſtals are rhomboidal.

To theſe properties may be added, that it does not precipitate either ſilver, mercury or lead, from their reſpective ſolutions in the nitrous acid: and that it gives out again its dephlogiſticated air in ſo pure a ſtate, as is hardly to be paralleled in air procured from any other ſubſtance.

The Epimuria natroſa *(Muriat oxygené de Soude)* is ſaid by the diſcoverer, M. *Berthollet*, to agree in moſt of its properties with this ſalt.

consisted of nine drachms and a half of volatile alkali, deprived of its fixed air; and six drachms and ten grains of concentrated marine acid. This salt may farther be prepared, and (where the latter substance is to be had in abundance) perhaps not without advantage, by mixing volatile alkali with the mother-water of common salt, as *Weber* has proposed. For the artificial composition of sal ammoniac, volatile alkali may doubtless be extracted cheapest from urine. The whole of the sal ammoniac, with which all Europe was supplied, was for a long time brought from Egypt. It is there prepared in manufactories erected for the purpose at Dsjise, as also at Giza (or Geeza) and Rosetto merely from the soot of the chimnies in that country, as is affirmed by competent eye-witnesses, such as *Hasselquist*, *Pocock*, and *Niebuhr*. The Egyptian soot is of a quite different kind from ours; because they burn no other fuel in that country than merely the dried dung of animals. Round, thin glass vessels with very short necks, two inches only in diameter, are filled with this soot to the distance of a few inches from their necks, coated on the outside a quarter of an inch thick with earth and chopped flax, and dried in the sun; over this a second coating of the same kind, half an inch thick, is laid, and dried in the same manner. These glasses are then placed in peculiarly constructed furnaces, capable of containing 20 or 24 of them, and a fire is kept under them for the space of 72 hours; in which time all the sal ammoniac is sublimed on to the upper part of the glass in the form of the segment of a sphere. Twenty-six pounds of soot, it is said, will yield about six pounds of sal ammonic. According to *Weber*, the soot of the Dutch turf also yields a perfect sal ammoniac by sublimation. The first sal ammoniac manufactories were established in England and Scotland; after these, one was set up at Paris by *Beaumé*, and another in Germany by the *Gravenhorsts*, two brothers, at Brunswick, which have been followed by divers others. After a previous purification, no difference can be made to appear between all the different specimens of real sal ammoniac. If it sublimes perfectly, it is fit for any use whatever. Though the constituent parts of sal ammoniac are perfectly well known, there are nevertheless a great many difficulties to be surmounted, when this salt is to be prepared in large quantities, so that it may be sold at a

To the history of the Epimuriatic acid may be added, that this acid, contrary to all others, does not effervesce with the effervescing fixed alkalies (or alkalies combined with fixed air). It enters however into union with them; as it loses its colour, and its smell is rendered much weaker than before, and is even altered in other respects. *Berthollet*. Mem. de l'Acad. des Sciences, 1786. [E]

reaſonable rate *. In ſome manufactories it is in the laſt place ſublimed; but in others it is inſpiſſated by evaporation, and moulded into the ſhape of a ſugar-loaf. The exiſtence of this ſalt in a native ſtate, may be proved by the writings of *Model*, as well as by its being met with at the apertures and fiſſures of the internal crater of mount Veſuvius, and likewiſe in the Solfatara, where it is found in maſſive lumps: and indeed ſal ammoniac is ſublimed through all the cracks and cavities of the lava, and is depoſited on its ſurface after it is cooled. This ſublimation, according to *Ferber*, has never been obſerved till two months after the eruption, which probably proceeds from this cauſe; that this ſalt exiſts, in fact, in very great abundance in the lava, and alſo muſt neceſſarily from the firſt moment be continually evaporating into the air; but that the ſublimation of it, in the red hot ſtate in which the lava is, is not perceptible, till it is ſo far cooled that the evaporating ſal ammoniac may attach itſelf to its now cooler ſurface. Hence we may form an idea of the amazing quantity of this ſalt that muſt exiſt in the lava that is thrown up. The purification of the Egyptian ſal ammoniac is performed by diſſolving it in boiling water in earthen veſſels; after which the lixivium is filtered, and ſet in a cool place to cryſtallize. But in caſe the ſal ammoniac ſhould happen to be blended with fixed ſalts, recourſe muſt be had to ſublimation, if they cannot be ſeparated from it by cryſtallization. With a moderate heat it attaches itſelf to the upper part of the veſſel quite in a looſe, ſpongy ſtate, and is then called *flowers of ſal ammoniac*; but if it be raiſed by a violent fire, a very ſolid ſublimate is obtained, which has the appearance of having been melted into one uniform maſs. This ſalt is indiſpenſably neceſſary on ſeveral occaſions; as for example, in ſoldering and tinning, as alſo in dying, not to mention other medical, chemical and pharmaceutical uſes. The cauſtic ſpirit of ſal ammoniac, according to *Weber's* experiments, produces, when ſaturated with marine acid, a ſalt which cannot be ſublimed ſo as to form a ſolid ſal ammoniac. Nothing can be ſaid preciſely as to the time when it was diſcovered. Its name occurs ſo early as in *Syneſius*; and *Geber* likewiſe mentions it in the catalogue of volatile bodies, among which he places it next to Mercury.

* Various propoſals to this end are to be found in *Weber's* Phyſico-Chemical Magazine for Phyſicians, Chemiſts, and Artiſts. Vol. I. *Berlin*, 1780. As alſo in *Alberti's* Introduction to the Sal Ammoniac Manufactory. *Berlin*, 1780. Likewiſe in *Goettling's* Eſſay towards an improved Method of making Sal Ammoniac. *Weimar*, 1782, 8vo. *F. A. C. Green's* Method of making Sal Ammoniac without Sublimation. Neueſte Entdeck. in der Chemie. Part IV. p. 19--38. And laſtly, in *Demachy's Laborant im Groſſen*. Vol. II. *Leipſick*, 1784. Being a tranſlation, with many improvements and Additions, of the "Deſcription des Arts et des Metiers." [A]

The

The neutral salts, arising from the pure *fluor acid*, are as yet but little known. As the common fluor acid in its preparation dissolves a pretty considerable portion of the siliceous earth of the glass retort, it must therefore be considered as an imperfectly saturated solution of siliceous earth in pure fluor acid. Hence arises its property of producing a jelly-like precipitate on being combined with alkaline salts. The saline liquid, however, that is left after this operation, is not a neutral salt; as, on the addition of fixed alkali, the neutral salt thence arising precipitates at the same time united with the siliceous earth, and consequently is not to be found in the liquor. The neutral salts, which are obtained from the pure acid as well with the *mineral** as the *vegetable* alkali †, cannot be brought to crystallize, but merely yield on evaporation a saline mass without any regular form, which precipitates lime-water, on which occasion the residuary fluid is a mere alkali, but the precipitate consists of regenerated fluor. In the same manner also these salts precipitate the solution of fixed sal ammoniac and of Epsom salt. In these instances therefore the pure fluor acid exhibits a greater affinity with calcareous earth and magnesia than with fixed alkali. The liquor remaining behind, after the mixture of *volatile alkali* with the above-mentioned acid, has nearly the taste of Glauber's sal ammoniac; on being evaporated, it yields *fluoric ammoniac* ‡ in small crystals, from which with a gentle heat a tender, acidulous salt may be sublimed. It also precipitates the calcareous earth from lime water, and likewise from its solution in the marine, or nitrous acid, and forms regenerated fluor; from which, when mixed with powdered chalk and water §, all the volatile alkali may be separated by distillation.

*Common Borax* consists of *sedative salt* and mineral alkali, which however are combined in it in such a proportion, as to give a great superiority to the mineral alkali. Hence it acquires an alkaline taste, and exhibits several alkaline properties. Consequently borax is an *imperfectly saturated neutral salt*. It is fusible in fire, and loses its water of crystallization on this occasion; it swells considerably, and at last melts to a substance like glass; which however is not glass, because it may be re-dissolved in water, and consequently still continues to

* Natrous Fluoricrate. † Spodic Fluoricrate. ‡ Ammoniacal Fluoricrate.

§ When pure neutral salts are intended to be produced from the fluor acid, this acid ought to be distilled in leaden or silver vessels; because that which is distilled from glass, in the precipitation of the siliceous earth by the two fixed alkaline salts, remains, together with the alkali, for the greatest part united with the earth. By not attending to this circumstance, many chemists, in analyzing the fluor acid, have been involved in a labyrinth of errors. [A]

 be

be borax. As to its other properties, borax is very well adapted for vitrifying earthy bodies, and metallic calces. When it is intended for this latter purpose, it is absolutely necessary for it to be previously calcined in earthen vessels, as otherwise, by its intumescence, it would throw the small metallic particles out of the crucible. The chemical art has nothing to do with the composition of this salt; as there can be no doubt remaining at present of its being solely the production of nature; for which reason all the attempts that have been made to produce it by art, have miscarried. As far as we have any certain information at this present time concerning it, all the borax comes in a raw, impure, though crystalline state from the East-Indies, China, Tibet and Persia, under the appellation of *Tincal*, and is, ab origine, a real native mineral salt. It seems that in those countries a greenish unctuous kind of earth is elixated with a particular species of water that comes down from the mountains, and the liquor afterwards left to evaporate gradually in the sun, in pits lined with a white kind of clay; from which there is obtained a greenish, yellow, or brownish, semi-pellucid salt*. The purification of it, which is now chiefly performed in Holland, was formerly supposed to be a peculiar secret; it is very certain however, that it is done merely by dissolving it in water without any farther addition, in the same way as is practised with most other salts. A true and faithful description of the process may be seen in *Ferber's* "New Contributions to the Mineral History of different Countries." Vol. I. p. 332. If we wish to convert borax into a *perfectly saturated neutral salt* †, it ought to be dissolved in boiling water, and sedative salt added to it till it loses all its alkaline properties. This will require a quantity of sedative salt, about equal in weight to the borax. *Wenzel*, in order to produce a perfect saturation, to 60 grains of mineral alkali, employed 250 of sedative salt.

From the saturation of the vegetable alkali with sedative salt arises a kind of salt, which is similar to the ordinary borax, and is called *Tartareous Borax* ‡, of

* Borax, according to Mr. *Blane*'s account, in Vol. LXXVII. of the Phil. Trans. is produced in a valley in Jemlate in the Tibethian mountains; being formed in reservoirs made by the side of a lake, six miles in circumference, the water of which is constantly hot, so that the hand cannot be held in it for any time. It is also very foul and greasy. In these reservoirs the snow is collected, and the hot water of the lake let into it. This, when evaporated by the heat of the sun, leaves a cake of borax half an inch thick. According to Father *Rovato*, or rather his correspondent, the prefect of the mission at Tibet, borax is produced in another valley in Tibet, at the bottom of certain pools. At the distance of about four miles from these pools there are salt-mines. Ibid. [E]

† Called *Natrous Borax*, to distinguish it from subacidated or *common Borax* (or natrum Boracicum.)

‡ Very improperly! rather *Spodic Borax*.

which

which however no particular uſe is known. This combination is indirectly and adventitiouſly obtained in the reſiduum left after the expulſion of the nitrous acid from nitre by ſedative ſalt. To ſaturate 60 grains of common fixed alkali, *Wenzel* employed 200 grains of ſedative ſalt.

*Boracic ammoniac* in like manner is a neutral ſalt, for which no particular uſe is known. It is obtained by ſaturating ſedative ſalt with volatile alkali, and concretes in ſolid cryſtals, which remain dry in the air, and nearly reſemble thoſe of borax; but, like the eſſential ſalt of urine, are decompoſed in the fire, the volatile alkali flying off from them. According to *Wenzel*, 60 grains of ſedative ſalt, ſaturated with volatile alkali, yield 55 grains only of neutral ſalt; but 63 grains of ſedative ſalt, which had loſt its water of cryſtallization by fuſion, yielded, on being ſaturated with volatile alkali, 85 grains of neutral ſalt.

As *Arſenic* partakes both of the ſaline and of the metallic nature, ſuch combinations may be made with it, in proportion as it is deprived of its phlogiſton, and in proportion to the different degrees of its ſaturation with the different alkaline ſalts, as may be conſidered as well in the light of true neutral as of metallic ſalts; ſince by phlogiſtic additaments, but eſpecially in combination with other metals, the metal, or regulus of arſenic may always be regenerated from them.

Thus from the combination of dephlogiſticated arſenic with mineral alkali ariſes a neutral ſalt, called *arſenical ſalt of Soda**. Theſe two ſubſtances may be combined together, either in a direct manner, or when the dephlogiſticated arſenic, by mixing with Glauber's or elſe common ſalt, and expelling by diſtillation from the former the vitriolic, and from the latter the marine acid; in both which caſes, the very ſame neutral ſalt is obtained from the reſiduum. It is remarkable of this ſalt, that it does not attract moiſture, even if the alkali be not perfectly ſaturated; and, on the contrary, acquires this property, when the alkali is ſuperſaturated with the acid. White arſenic, which ſtill contains a portion of phlogiſton, cannot ſo eaſily expel the marine acid from the common ſalt; but when it is diſtilled with quadrangular nitre, Natrous Arſenicrate is in like manner obtained from the reſiduum. *Macquer* calls the combination of white arſenic with mineral alkali, which has the property of forming cryſtals, *Liver of Arſenic* with *baſis of mineral alkali*.

From dephlogiſticated arſenic, or the acid of arſenic, as it is called, combined with vegetable alkali, ariſes a ſalt, which concretes in tetraëdral priſms,

* *Natrous Arſenicrate.* [E]

terminated

terminated by pyramids with four equal ſides. It does not differ from that which is obtained from the reſiduum of equal parts of white arſenic and nitre mixed and diſtilled together, and which is called by *Macquer*, *neutral arſenical ſalt*, or *arſenical ſalt of tartar* *. From this neutral ſalt the *fixed arſenic*, obtained from a mixture of equal parts of nitre and arſenic, by projecting them into a red hot crucible, differs in this circumſtance, that in the latter a ſmall quantity only of arſenic is found remaining, moſt of it having been detached during the fuſion and driven up the chimney; whence the whole maſs contains a large quantity of redundant alkali has an alkaline taſte, and deliqueſces in the air. Of the ſame nature alſo is the *common liver of arſenic*, which is generated by boiling the common white arſenic with a lixivium of fixed alkaline ſalt, till it has diſſolved as much arſenic as it poſſibly can; upon which the ſaline lixivium is evaporated. After a few days expoſure to the air it will become moiſt, and acquire the appearance of a viſcid mucilage. This combination has a diſagreeable ſmell, and continues ſtill to be alkaline. It is an eſſential requiſite, with reſpect to arſenical neutral ſalts in general, in caſe they are expected to cryſtallize, that they ſhould contain a redundancy of the arſenical acid. In the two latter caſes this requiſite condition is not fulfilled; on which account alſo no cryſtalliſation is obſerved. *Deliquiated arſenic* (liquor arſenici per deliquium) is obtained, by ſuffering the above mentioned fixed arſenic to deliqueſce of itſelf in a moiſt place.

In the ſame manner alſo may be prepared an *arſenical ammoniac* †, by ſaturating dephlogiſticated arſenic with pure volatile alkali; as likewiſe by expelling the marine acid from ſal ammoniac by means of dephlogiſticated arſenic. This ſame ſalt, on diſtilling white arſenic with an equal weight of nitrous ammoniac, is obtained from the reſiduum; by which means the nitrous acid is diſengaged and paſſes into the receiver. *Macquer* called it *arſenico-ammoniacal neutral ſalt*; it concretes in needle-like cryſtals, that are long and flat, and ſharp at each end, and lie promiſcuouſly and without order one upon the other. In a ſtrong heat this combination is alſo deſtroyed again in cloſe veſſels; the volatile alkali comes over, and the arſenic is ſublimed. White arſenic may alſo be diſſolved by volatile alkali, viâ humidâ, and form a ſimilar ammoniacal combination.

The *Acid of Molybdæna*, united with *fixed alkali*, is by this means made more ſoluble in water, and on cooling concretes in ſmall irregular cryſtals, which ceaſe to be volatilized by an open fire ſo eaſily as before. Combined with *volatile alkali*

* *Spodic Arſenicrate.* [E]

† Ammoniacal Arſenicrate. [E]

it yields a peculiar ammoniacal ſalt, which in a very moderate heat ſuffers the volatile alkali to eſcape, and leaves a grey powder at the bottom of the retort.

The *Barylithic* or *Tungſtenic acid*, diſſolved in water, yields with *vegetable alkali* a neutral ſalt, which concretes in very ſmall cryſtals; but produces with *volatile alkali* an ammoniacal ſalt in ſmall cryſtals, reſembling the points of needles. In the diſtillation of the latter, cauſtic volatile alkali is diſengaged, and a dry yellow powder is left behind in the retort. This ſpecies of ſal ammoniac is alſo decompoſed by a ſolution of calcareous earth in the nitrous acid, and by this means a regeneration of the lapis ponderoſus or Tungſten takes place.

The *phoſphoric acid*, with a ſmall ſurplus of acid forms with *mineral alkali*, merely a viſcid, gummy, tranſparent maſs, which is ſolid in the cold and fluid in heat. But with a ſurplus of mineral alkali, or even when perfectly ſaturated with it only, cryſtals are obtained that do not deliqueſce in the air, are of eaſy ſolution, and on being expoſed to the fire, fuſe without frothing up, and form a tranſparent vitreous maſs (alkali minerale phoſphoratum) *, which however becomes opaque on cooling. This is the famous *ſal perlatum of Prouſt*, or *Rouelle*'s *fuſible ſalt of urine*. This ſame acid, with the *vegetable fixed alkali*, produces a perfect neutral ſalt, the cryſtals of which conſiſt of ſhort, and ſomewhat compreſſed priſms (alkali vegetabile phoſphoratum) ‡. It is decompoſed again by lime water; this is alſo effected by water containing ſelenite. It is not decompoſed by fire, but only fuſes to a vitreous maſs, which however is again ſoluble in water. With volatile alkali, this acid produces *phoſphoric ammoniac* § (ſal ammoniacum phoſphoratum, alkali volatile phoſphoratum) a ſalt, which concrets in oblong ſpicular cryſtals, and parts with its volatile alkali in a red heat, in this reſpect reſembling another ſalt, which occurs under the name of the *natural fuſible ſalt of urine* (ſal eſſentiale fuſibile urinæ, ſal microcroſmicum) which later inveſtigations have ſhewn to be a compound neutral ſalt, in which the phoſphoric acid is partly ſaturated with mineral and partly with volatile alkali ‖. The moſt uſual method of extracting it from urine is as follows: a large quantity of it, either freſh or putrid, is evaporated to the conſiſtence of a thin ſyrup; upon this the veſſel is ſet in a cool place, and in the ſpace of a month, priſmatic cryſtals will concrete in it of a ſlightly ſaline taſte and a reddiſh-brown colour. The remaining liquor being decanted, theſe cryſtals are again diſſolved in as much warm water as is requiſite;

* When merely ſaturated with alkali, *Photocraticum Natroſum*; and with a redundancy of alkali, in which ſtate it conſtitutes *Haupt*'s ſal perlatum, it may be called *Natrum Photocraticum*. [E]

‡ Photocratium Spodicum. § Ammoniacal Photocrate. ‖ Photocratium Ammoniaco-natroſum. [E]

and the filtered lixivium immediately set in a cooler place, when, in the space of five days, finer and purer cryſtals are obtained. Theſe may afterwards be diſſolved once more in warm water, filtered and cryſtallized, till they have acquired the requiſite whiteneſs. The liquor remaining after the firſt cryſtallization, as likewiſe all that is left after the preceding purifications, may be diluted with water, filtered, evaporated, and again ſet by in a cool place, when cryſtals are once more formed, which, however, are commonly diſtinguiſhable from the former by their oblong-ſquare figure, and ought not to be confounded with them. One hundred and twenty Berlin quarts of urine yielded to M. *Marggraf* no more than from three to four ounces of pure white cryſtals. This ſalt has a cooling taſte, remains unchanged in a warm air, does not decrepitate on red-hot coals, but ſwells up and froths like borax, and with a more intenſe heat fuſes to a tranſparent vitreous body, which attracts the moiſture of the air, diſſolves in water, and has an acid taſte, becauſe in its expoſure to a red heat it has parted with the volatile alkali.

Inſtead of the preceding troubleſome proceſs, M. *Bucholtz*, following the track of *Iſaacus Hollandus*, has publiſhed the following *improved mode of preparation*. The whole portion of the lixivium of ſalt of urine produced by one hundred and thirty pounds of urine, (from which, after the proper rectifications, ten pounds of ſtrong ſpirit of urine had been previouſly obtained by diſtillation in a copper alembic with a pewter head and tube,) is evaporated perfectly to dryneſs in an iron pot, and the concrete black matter afterwards expoſed to a red heat in a crucible, till all the foul oily ſubſtance, which is, in truth, what prevents the cryſtallization, is conſumed by the fire. Upon this the reſidual black matter is elixated with water, and as much of the volatile alkaline ſpirits that has been drawn off in the beginning, is added to the ſaline lixivium over the fire, as is requiſite for its perfect ſaturation. This being gradually evaporated, and ſet by to cryſtallize, four ounces and a half of cryſtals will be obtained in the form of a lozenge, which are the genuine fuſible ſalt of urine. Great care however ſhould be taken in this operation, not to confound with theſe, the other cryſtals that are alſo produced in it, and which differ from the former in their figure, taſte, and other properties. The above deſcribed method of obtaining this ſalt from urine by mere evaporation, which has been followed by *Marggraf* and others, ſhews that it is actually contained in the urine; but as the volatile alkali is expelled from it by the fire, it becomes neceſſary that the ſalt which, in the ſeparation and purification

cation of it, viâ ficcâ, has been expofed to a red heat in the fire, fhould be faturated again with volatile alkali; in cafe it is required to be perfectly fimilar to the natural falt.

In like manner may three different forts of neutral falts be prepared from the *acid of amber*, though they are not much known, nor at prefent, one of them only excepted, particularly ufed. From this acid faturated with *mineral alkali*, *Wenzel* obtained a neutral falt, which concreted in long, thin cryftals, in the form of faw-duft, and fuffered no change from the moifture of the air. But according to *Leonhardi*, the cryftals are of a foliated form, with truncated triedral prifms. This falt has the appellation given it of *Soda of Amber**. From the fame acid and the *vegetable alkali*, *Wenzel* obtained a falt which did not cryftallize, and after exficcation, deliquefced again when expofed to the air. On the other hand, *Stockar de Neuforn*, from the combination of acid of amber and the laft mentioned alkali, obtained fhining, pellucid cryftals, in the fhape of falt of amber. They had a peculiar tafte, and were eafily diffolved in cold water. From the very fame combination, *Leonhardi* obtained a falt of eafy folution in water, of a foliated texture, and which concreted in the form of triedral prifms, which he called *fuccinated Tartar* †. With regard to their fixity, *Wenzel* fays, that the two forts of neutral falts mentioned above, were decompofed in the fire, and the fixed alkali only remained. *Stockar de Neuforn*, on the contrary, affirms, that the latter neutral falt prepared with vegetable alkali, when ftrewed upon red-hot coals or iron, decrepitated, fufed, but remained fixed and unaltered in its properties as a neutral falt. On this point *Leonhardi* agrees with him, who affirms of thefe two neutral falts, that they decrepitate gently in the fire, without fuffering any decompofition. Finally, from this very fame acid and *volatile alkali*, is obtained at laft, *fuccinated ammoniac* ‡, which, according to *Leonhardi*, cryftallizes in the form of fmall needles, and in clofe veffels is totally fublimed; in which point, both *Stockar de Neuforn* and *Wenzel*, accord. Of this latter kind is the fpirit of hartfhorn mixed with falt of amber, and ufed in medicine, (liquor cornu cervi fuccinatus). All thefe neutral falts have a bitter faline tafte; and none of them form aqua regia on being mixed with nitrous acid. The *acid of ambergrife*, on account of its great price, has not as yet been applied to the formation of any neutral falts.

* It might have been more fcientifically intitled, *Natrous Electrocrate*. [E]

† Better, *Spodic Electrocrate*. [E]

‡ *Ammoniacal Electrocrate*. [E]



In

In like manner the *manifest* and *liquid vegetable acids* may be united with alkaline salts, so as to form neutral salts; but these combinations are as yet but little known. M. *Wenzel* has made experiments for this purpose with the *acid of lemons* only, and has remarked, that half an ounce of lemon juice took about a scruple of *mineral alkali* to saturate it. According to Dr. *Donald Monro's* account, this salt concreted in crystals, the greatest part of which were irregular; part of them however were found to be rhomboidal, pentogonal, polyedral, or of a narrow, oblong, parallelogramatic form, of the size and appearance of grains of barley or wheat, which latter crystals at a distance appeared round, but on closer inspection, exhibited six plane surfaces, and two apices consisting of two plane surfaces converging together, so as to form an obtuse wedge. This salt might be called *Soda of Lemons**. The same quantity of this acid took about two grains of *vegetable alkali*, weighed out while it was hot, to saturate it. This latter cannot be crystallized on account of the mucilaginous particles still contained in the juice, and for this very reason it is that the respective proportion of both cannot be precisely determined. From its constituent parts, this salt might be termed *Tartar of Lemons*†; it is however employed in medicine under the appellation of *Riverius*'s draught. Twenty grains of volatile alkali required nearly four drachms and a half of acid of lemon for their saturation. The latter combination, which might be called *Ammoniac of Lemons*‡, forms thin, needle-like crystals, which have a mild, saline, and cooling taste.

With respect to the *occult* and *liquid vegetable acids*, three different neutral salts are in like manner prepared with the *acetous* acid, by combining it with alkalies, which salts are also applied to different uses. The first is the *vinegar of soda*§, or *crystallizable foliated salt of tartar*, (terra foliata tartari crystallizabilis, or sal diureticum veget. crystalliz.) which was first prepared by *Baron*. This is obtained by perfectly saturating purified salt of soda with distilled vinegar, till no farther effervescence is perceptible on a fresh addition of the acid; after which the liquor is to be filtered and evaporated, till a pellicle appears, and then set by for crystallization. Sometimes too, this combination is made adventitiously; e. g. in precipitating a solution of sugar of lead with salt of soda, or likewise, in separating sedative salt from borax, by means of concentrated acid of vinegar; in like manner, in mixing a solution of Glauber's salt with a solution of chalk in vinegar.

* But perhaps still better. *Natrous Citrocrate.* [E] † Or rather, *Spodie Citrocrate.* [E]
‡ More properly, *Ammoniacal Citrocrate.* [E] § More properly, *Natrous Oxycrate.* [E]

The

The other salt, is the *foliated earth of tartar*, which with equal impropriety, is called *regenerated tartar*, more properly, *acetous tartar**. For this purpose, upon a quantity (ad libitum) of purified vegetable alkali, distilled vinegar is poured into an earthen vessel; this is evaporated, and the pouring in of vinegar continued, till no farther effervescence is observed, and the mixture during evaporation yields a sour smell of vinegar. After this, the liquor is filtered, and evaporated to dryness.—But notwithstanding the greatest precaution being taken with this preparation, still the salt will unavoidably have somewhat of a grey or brownish colour. It is probably for this reason that it has obtained the appellation of an earth.—This colour proceeds from some oily and mucilaginous particles carried up by the vinegar in distillation, which are disengaged in the saturation of the vinegar with the alkaline salt, and render the salt impure. Our ancestors had no objection to the grey colour, and made use of the salt in this state. But in our time it is required to be pure, and therefore ought to be freed from those particles which give rise to this colour. For this purpose various methods have been used, of which some tended to the prevention, and some to the removal of the colour. With a view to the former, *Cadet* advises us to supersaturate the neutral lixivium with a little distilled vinegar. *Beaumé*, on the other hand, requires only the half of the distilled vinegar, which comes over first, to be applied to this purpose of making this salt, as the other half, which it must be owned is much more acid, may be put to some other use. He gives for his reason, that as the strength of the vinegar continually increases in the distilling vessel, its acrimony and acidity also must act in a greater degree upon the oleaginous constituent parts; whence in the latter half of the distillation, a greater quantity of these must be forced over, by which means the vinegar contracts an offensive smell, and the salt a dark hue. As to the other intention, which is to remove the brown colour, repeated solution in cold water, and frequent filtration have indeed some effect; but a perfectly purified salt is hardly to be obtained by these means. *Cadet* affirms, that this purification may be successfully performed by a mere solution of the impure salt in a sufficient quantity of distilled vinegar, by filtration; and very gentle evaporation.—In my opinion, this end may be best effected by fusing the inspissated brown saline mass in an iron pan, over a

* More properly, *Spodic Oxycrate*. [E]

pretty brisk charcoal fire, till there are no more lumps to be seen in it. By these means it becomes quite liquid like water, and acquires a dark-brown colour. But the fusion ought to be performed with all possible expedition, the salt removed as soon as it is melted, and, when it has become quite cold, a sufficient quantity of water poured upon it. As soon as it is dissolved, the lixivium, which now will have a much lighter colour, is to be filtered: but as most commonly, in this mode of purification, a small quantity of the acetous acid has suffered combustion, the lixivium, though it has been perfectly saturated before, is now however found to be somewhat alkaline: for which reason neither must the calcination be continued too long. In order to obviate the trifling disadvantage abovementioned, it will be necessary in the latter evaporation of the lixivium, to add a little more distilled vinegar, till the saturation is complete, and directly afterwards to evaporate the salt to dryness, by a gentle fire; when a fine white salt will be obtained*. This salt is of a very deliquescent nature, and will never crystallize; it may however, according to others, be made to crystallize by means of the aerial acid. By the deliquiation of it in the open air, is obtained the *liquor terræ foliatæ tartari per se*, which is used in medicine; also another weaker liquor is prepared from it, by dissolving it in two or three times its quantity of distilled water. This salt has the advantage of many others, being soluble in great quantities in spirit of wine; which, if done in the same proportion as with distilled water, the liquor is called *Arcanum tartari dulce*. According to *Boerhaave*, this saline composition may also be prepared at a cheaper rate for the use of the poor, with crude undistilled vinegar; in which case however it will be most convenient not to evaporate the salt to dryness, but to such a point only, that it may be used immediately in a liquid form. From a perfectly saturated combination of the acetous acid with the volatile alkali, is produced an ammoniacal compound, which may be termed *acetous ammoniac*, but which is better known by the name of *Mindererus's spirit* †. This mixture is always used in a liquid form, because it is

* A still better way of whitening this salt, is to add some powdered charcoal towards the end of the evaporation; and after separating the liquor from the coals by filtration, boil it down to a proper consistence. [E]

† More scientifically, *Ammoniacal Oxycrate*.—As the distilled vinegar with which the Spiritus Mindereri is made, is seldom of the same strength, this salt consequently will be found different, in different shops. To remedy this inconvenience, Mr. *Dollfuss* in his *Pharmaceutisch-Chemische Erfahrungen*, proposes the following formula: but the medicine must be exhibited in a much smaller dose than the ordinary spirit of our dispensary.

Let

is not cryſtallizable, and will not bear evaporation, inaſmuch as on being ſubjected to diſtillation, theſe ſpirits come over as a liquid ammoniacal ſalt. It is true, that according to *Weſtendorf's* experiments, cryſtals may be obtained with the concentrated ſmoking ſpirit of vinegar,* which however ſoon deliqueſce again; but when cauſtic ſpirit of ſal ammoniac was employed for this purpoſe, no cryſtals at all were formed. The pure *Lignic acid* with alkaline ſalt, produces neutral ſalt, which are very ſimilar to thoſe mentioned before.

Various neutral ſalts moreover are obtained from the remaining, viz. the *concrete, occult acids* of the *vegetable* kingdom. They are partly produced by Nature, and partly by art. The native ſalts of this kind, are thoſe *eſſential* ſalts of *vegetables*, which conſiſt of a vegetable acid and an alkaline ſalt, of which we have inſtances in *ſalt of wood-ſorrel* and *tartar* *.

Eſſential ſalts of this kind muſt be extracted from green juicy vegetables. For the purpoſe of preparing ſalt of *wood-ſorrel*, for example, the wood-ſorrel, (*oxalis acetoſella Linn.*) is bruiſed in a mortar, and the whole of its juice expreſſed. After it has ſtood for ſome time, the groſſer earthy particles ſubſide to the bottom, and the liquor becomes limpid and clear, after which it is filtered. The clear juice is then evaporated to leſs than one half, and ſet by in a cool place, to cryſtallize. After ſome time, the remaining liquor is poured off from the cryſtals, and then evaporated, filtered, and cryſtallized afreſh. In fine, this proceſs is continued

Let one ounce of ſugar of lead be mixed with half its weight of ſal ammoniac, and this mixture be diſtilled with a very gentle heat; what comes over into the receiver, is a very ſtrong ammoniacal oxycrate.

Another, but mnch weaker ſpirit, may be obtained by the following method: Four ounces of purified vegetable alkali are to be ſaturated with vinegar, and then evaporated to 36 ounces. In this liquor let three ounces of crude ſal ammoniac be diſſolved; when the whole is to be put into a retort, and 24 ounces drawn off by diſtillation. This forms an excellent Spiritus Mindereri. [E]

* Beſides this, the following eſſential ſalts of this kind are known: The ſalt of the *Craneſbill*, (Geranium peltatum, and alſo acetoſum), from the juices of which, *Cartheuſer* obtained a ſalt of a pretty ſtrong acid taſte, in the form of ſmall white cryſtals, by mere filtration, evaporation, and cryſtallization. The ſalt extracted from the berries of *Sumach*, (Rhus coriaria Linn.): Profeſſor *Trommſdorf* ſeparated from it, by elixating the berries with hot water, and afterwards evaporating the liquor. Laſtly, the acid ſalt of *Tamarinds*, which, to the beſt of my knowledge, was firſt made public by *Angelus Sala*. In order to obtain this, two pounds of tamarinds are beat up with ſix pounds of cold, or rather luke-warm water, till by this means all the acid taſte is extracted out of them. The liquid part is then ſeparated from the reſt of the maſs by expreſſion, and afterwards poured off clear, evaporated and cryſtallized.

till the whole of the ſalt is extracted from the juice. According to *Savary's* experiments, 50 pounds of freſh wood-ſorrel yielded 25 pounds of juice, from which were obtained two ounces and a half of pure ſalt. This ſalt conſiſts of a peculiar acid, which for this reaſon is called acid of wood-ſorrel; and of common fixed alkali, as I have proved in a ſeparate Treatiſe on this ſubject. Conſequently it is a natural ſalt, but a neutral ſalt ſuperſaturated with acid. When it is combined with more alkali, ſo as to be ſaturated with it, very peculiar neutral ſalts are produced by it. From the ſaturation of ſalt of wood-ſorrel with mineral alkali, *Wenzel* obtained a few ſmall cryſtals only, reſembling alum. The greater part of them ſhot up perpendicularly into the air, from the ſides of the veſſel; and preſerved indeed their form in the air, but were eaſily diſſolved in water. So that in this ſalt, two different kinds of alkali were combined with an acid. 377 grains of ſalt of ſorrel ſtill ſaturated two drachms of very dry mineral alkali, with the redundant acid it contained. Salt of ſorrel ſaturated with the ordinary fixed alkali, produced a neutral ſalt, which, according to *Wenzel*, partly concreted in long priſmatic cryſtals, though the greater part of the cryſtals were compoſed of large laminæ, lying one upon the other, with four, ſix, and more diſſimilar ſurfaces. Here, no more than 294 grains of ſalt of wood-ſorrel were requiſite for ſaturating two drachms of the ordinary alkali with the redundant acid contained in them. According to my own experiments upon two different ſorts of ſalt of wood-ſorrel, half an ounce of one of them took four drachms and a half of ſalt of tartar to ſaturate it, while the ſame quantity of the other required no more than three drachms and a half. From the former ſort I obtained laminated, oblong, rhomboidal cryſtals, which had concreted one over the other, almoſt in the ſame manner as the ſalt of ſorrel itſelf. From the latter ſort I obtained a neutral ſalt, of which, ſome of the cryſtals were extremely ſmall, and cohered together, while others were large, with rhombical ſurfaces, and pretty much reſembled borax. Theſe neutral ſalts precipitate the earth from ſpring-water, and taſte almoſt like cryſtallized ſoluble tartar. Salt of ſorrel ſaturated with volatile alkali yields a peculiar ſalt, in which the pure acid is ſaturated with the ordinary fixed and the volatile alkali, and which, according to *Wenzel*, concretes into cryſtals, in ſhape reſembling needles, and does not deliqueſce when expoſed to the open air.

The pure *acid* of *wood-ſorrel* combined with *mineral alkali* to the point of ſaturation, produced in *Savary's* experiments, a neutral ſalt, which formed large cryſtals, and fell to powder on being expoſed to the open air. From the ſame acid

acid and the *ordinary fixed alkali*, a neutral ſalt was produced, which was very ſoluble, and in like manner concreted into cryſtals. From *volatile alkali* ſaturated with this acid, white ſilk-like cryſtals were obtained, which on being ſublimed, parted again with the greateſt part of the volatile alkali. Since we know that the acid of wood-ſorrel is not eſſentially different from the acid of ſugar *, it follows, that the neutral ſalts, which we have deſcribed here, are alſo not eſſentially diſtinguiſhed from thoſe which ariſe from the acid of ſugar, pag. 244 & ſeq.

The other eſſential acid ſalt known to Chemiſts, viz. *tartar*, is pretty nearly of the ſame nature. In fact, it is a neutral ſalt, compoſed by Nature, of the proper and ſpecific acid of tartar and vegetable fixed alkali. But as the acid abounds greatly here in compariſon with the alkali, it is a neutral ſalt ſuperſaturated with acid. It is, in fact, the eſſential ſalt of wine, which after a certain time ſeparates from young wines, and adheres to the internal ſurface of the caſks, in the form of a thick cruſt. It was erroneouſly ſuppoſed to be generated by fermentation: but *Roulle*, the younger, firſt, and after him, many others, ſeparated it from the freſh juice of grapes. Red wine yields a red tartar, and white wine a white tartar. Acid wines yield the greateſt, and ſweet wines the ſmalleſt quantity. As its acid is not volatile, and is deſtructible by fire, it yields on being diſtilled ſeparately by itſelf, an empyreumatic ſpirit, called *ſpirit of tartar*, (ſpiritus tartari), which exhibits but ſlight traces of the preſence of an acid. Next after this comes over the helm likewiſe a ſmall quantity of empyreumatic oil. In the alembic there remains a coal, in which is contained

* For our knowledge of this ſalt, and the true nature and method of regenerating it by art, we are indebted to the immortal *Scheele*. The analogy of this ſalt with the acid of ſugar, induced him to examine it farther; and after a few unſucceſsful attempts, he diſcovered the mode of regenerating it. Having diſſolved as much acid of ſugar in cold water, as the water could take up, he added to this ſolution ſome lixivium of tartar, drop by drop, waiting a little after each drop; and found the mixture, during the effervescence, full of ſmall cryſtals, which were genuine ſalt of wood-ſorrel. The identity of the acid of wood-ſorrel with that of ſugar, has not only been proved by M. *Scheele* himſelf, but by ſeveral other chemiſts, particularly M. *Klaproth* of *Berlin*, by means of a very curious and ſtriking experiment. This gentleman precipitated a ſolution of quickſilver in nitrous acid with ſalt of wood-ſorrel perfectly neutralized by vegetable alkali, and obtained a white precipitate, which, when edulcorated and dried, and gently heated in a tea-ſpoon, produced a fulminating noiſe, not inferior to that of fulminating gold. Acid of ſugar, perfectly neutralized with vegetable alkali, afforded the ſame precipitate and exhibited the ſame fulminating power. [D]——Hence they are now very properly confounded together under the denomination of the *Oxaline* acid: the *Oxalis*, or wood-ſorrel containing this acid native and ready prepared. [E]

the

the fixed alkali, and from whence this latter is elixated by water: this lixivium is afterwards purified by filtration, and evaporated to dryneſs. The weight of it generally amounts to four ounces, in each pound of tartar. The practice of urging the coal in open veſſels with a white heat, is more prejudicial than advantageous to the alkali. The difficult ſolubility of tartar in water, does not at all proceed from the earthy parts, as is ſuppoſed by ſome; becauſe purified tartar is equally difficult to diſſolve. The conſtituent parts of tartar, when ſeparate, have a great affinity with water, which however diminiſhes the inſtant they are united. For in conſequence of the original form of the cryſtals being altered, the degree of affinity which they bear to other bodies muſt likewiſe be different from what it was before. The purification of tartar is never attempted in ſmall quantities; neither indeed does the experiment ſucceed if not performed on a large ſcale. In different parts of *France*, as at *Montpellier*, *Calviſſon*, and at *Agnane* in *Languedoc*, there are extenſive manufactories, in which ſolely this proceſs is carried on, and whence the purified tartar is exported to other countries*. The chief of the proceſs, as *Fizes* has deſcribed it, conſiſts briefly in this: Firſt, the tartar is diſſolved in boiling water, and ſtrained, in order to free it from its groſſer impurities and earthy parts. Upon this, the tartar which has now cryſtallized afreſh, but is ſtill coloured, is again put into large boilers with water previouſly impregnated with a ſaponaceous or ſandy argillaceous earth, which neither efferveſces with, nor is ſoluble in any acid. In this manner it is again diſſolved by boiling, and at the ſame time, freed by this earth from all the impurities it may ſtill contain. So that now, perfectly white cryſtals are obtained, known by the name of *Cryſtals of Tartar*, (Cryſtalli Tartari). From this the *cream of tartar*, (cremor tartari), is no otherwiſe diſtinguiſhed, than that the latter conſiſts of nothing but ſmall cryſtals cohering with each other, and in this combination forming a ſaline cruſt. It would therefore appear rather ſingular for any one to require, that, conformably with the old formula, the purified cryſtals of tartar ſhould be boiled

* Tartar is alſo refined at *Venice*, where they uſe the whites of eggs in order to clarify the ley: to which, undoubtedly with great loſs to the manufactory, they alſo add wood-aſhes. Vid. Chem. Journal, Vol. VI. pag. 138---147. [A]

*Fizes* and *Demareſt* affirm, that the tartar at Montpellier and Venice is cryſtallized in copper veſſels. Theſe cryſtals, as Dr. *Zoebel* obſerves in the Beytrage zuden Annal. Vol. II. pag. 7. though larger and more beautiful, are not ſo white as thoſe that are formed in wood, from which they are diſtinguiſhable by a greeniſh caſt. Many years ago, a ſolution of this ſalt in boiling water was very much in vogue, under the name of *Imperial Tea*; but the complaints in the ſtomach and bowels almoſt univerſally occaſioned by a conſtant uſe of it, ſoon brought it into diſrepute, and have ever ſince deterred many people from taking a medicine, which, when genuine, appears to be not only innocent, but capable, by a long-continued uſe, of producing the beſt effects. [E]

with

with a large quantity of water, and the ſaline pellicle, which appears on the ſurface, taken off, till at laſt all the cryſtals ſhall be converted into ſuch pellicles. This pulverized ſaline pellicle and the pulverized cryſtals of tartar, are in all probability identically the ſame. As tartar ever ſince, till within this ſhort ſpace of time paſt, has been conſidered as a mere acid ſalt, which has acquired a concrete, ſolid form merely by means of the earthy and oily particles combined with it; it has accordingly been uſed as an acid for the preparation of divers neutral ſalts; but it anſwers this purpoſe by means of the acid only which is contained in it beyond the point of ſaturation.

The neutral ſalts generated from tartar by means of the alkaline ſalts, are all uſed in medicine.—By the combination of it with mineral alkali, is produced the *ſalt of Seignette*, (ſal polychreſtum Seignetti), which, in fact, is a double neutral ſalt *. It takes its name from an apothecary at *Rochelle*, who with a view to profit, made a ſecret of it for a long time. *Lemery* makes ſome mention of it ſo early as in 1675. But the actual diſcovery of it was not made till the year 1731, by Meſſrs. *Boulduc* and *Geoffroy*. It is prepared in the following manner: A quantity of genuine ſoda is boiled in water till all the ſaline particles it contains are diſſolved, after which the lixivium is filtered; and to this, while it is ſimmering over the fire, are added pulverized cryſtals of tartar, till no more effervescence is to be perceived. The ſaline lixivium is then filtered again, andſuffered to evaporate over a gentle fire, till ſome drops of it, that are let fall on a cold iron, are obſerved immediately to cryſtallize, after which the liquor is poured into a flat earthen veſſel, and put by to cryſtallize. The liquor, which remains after cryſtallization, is now evaporated and cryſtallized afreſh, and this proceſs is continued till all the ſalt is ſeparated from it. Very lately *Scheele* alſo publiſhed another mode of preparing this ſalt.---Thirty-ſix ounces of cryſtals of tartar are ſaturated with pot-aſh, and in this ley are diſſolved eleven ounces of common ſalt. When it is grown cold, and the vitriolated tartar has ſubſided to the bottom, it is filtered and evaporated, till a pellicle appears. The two firſt cryſtallizations yield a fine ſalt of Seignette; but the third contains a ſmall portion of digeſtive ſalt; and the fourth is entirely compoſed of it. This circumſtance depends on the tartarus tartariſatus in part, and the common ſalt

* This, as well as the Soluble Tartar, a little farther on, is by *Bergman* with greater propriety termed a *triple* ſalt, and may be called *Tartarus ſpodico-natroſus*. [E]

making a mutual exchange of their respective constituent parts, insomuch that a part of the acid of tartar unites with the mineral alkali of the common salt, while the marine acid unites with the vegetable alkali that was added to the mixture. Two drachms of mineral alkali take 330 grains of crystals of tartar to saturate them completely *.

Here likewise deserves to be mentioned a neutral salt, of a peculiar composition, which was first prepared and made public by *Le Fevre*, a physician at *Ulm*, in the year 1732. For this purpose four ounces of pulverized crystals of tartar are mixed with two ounces of borax, and boiled in a vessel of stone-ware with twenty ounces of water, by which means all the salt is dissolved †. The lixivium is then filtered, and gradually evaporated to dryness. In the beginning of the operation, this salt acquires the form of honey or turpentine; but if the evaporation is continued, it resembles in colour and consistence the gum of the plum-tree. This neutral salt might be discriminated from the others by the name of *Boracic Tartar*, or *Tartar of Borax*. It is in fact a species of soluble tartar, and dissolved in water with uncommon facility; it is also very easily liquified by the moisture of the air, and ought therefore always to be kept in a warm place, in vessels closely stopped. It is for the same reason uncrystallizable; but what is chiefly remarkable in this salt is its acid taste, which is much more poignant than that of mere tartar.

When, on the contrary, tartar is united with the vegetable alkali to the point of saturation, it produces *tartarized tartar* (tartarus tartarizatus), a salt which is very easily dissolved in water, and has hence obtained the name of *soluble tartar*

* According to *Wenzel* and *Gottling*, the salt of Seignette may likewise be obtained in the following manner: Six parts of crystals of tartar are saturated with pot-ash, and five parts of Glauber's salt are afterwards added to this mixture. If too much water be not used, the vitriolated tartar obtained by this means will, soon after the mixture of these salts, be separated in the form of a powder: otherwise it must first have time given it to crystallize. After it the salt of Seignette will crystallize. Vid. *Wenzel's Doctrine of the Affinity of Bodies*. page 469. *Gottling's Chemical Essays*. [Chemische Versuche], *Weymar* 1782, pag. 135. [A]

† As I have frequently experienced a great difference in different parcels of borax, and once found, that to one part of this salt I was able to put three of crystals of tartar, which were altogether made soluble by the borax, it will be safer to dissolve the borax first in water, and, while it is on the fire, to add crystals of tartar, till no more of them will dissolve. [A]

(tartarus solubilis) *. It is acquired by dissolving in water a quantity, ad libitum, of purified, fixed vegetable alkali, and adding to it, while it is boiling hot, pulverized crystals of tartar till no farther effervescence can be perceived. The saturated lixivium upon this is filtered, and evaporated to dryness over a gentle fire. When the salt is thoroughly saturated, it is not so easily crystallized as when it still contains a small quantity of unsaturated alkali. This salt, as well as that of Seignette, is decomposed in such a manner by free and uncombined acids of all kinds, either mineral or vegetable, that they unite with that portion of alkaline salt, by which the tartar has been converted to a perfect neutral salt, and precipitate the whole tartar from it in the form of a fine crystalline powder. Two drachms of purified vegetable alkali require 295 grains of crystals of tartar for their saturation.

From Tartar, finally, when saturated with volatile alkali, a neutral salt is obtained, which also has received the name of *Soluble Tartar* (Tartarus Solubilis); though, for the sake of distinguishing it from the preceding salt, it would be better termed *Tartareous ammoniac*. This is also a double neutral salt, since it contains both the common fixed and the vegetable alkali, which are both saturated with the acid of tartar. To prepare this, a quantity (ad libitum) of pulverized crystals of tartar are thrown into a proportionate quantity of water, to which, whilst it is boiling, a quantity of volatile alkali dissolved in water is added by little and little, till nomore effervescence is observed. Immediately upon this the lixivium is filtered, and evaporated to dryness. *Wenzel* employed nearly one drachm of concrete volatile alkali on the saturation of half an ounce of crystals of tartar.

From what has been mentioned above, it is easy to perceive, that the *pure acid of tartar*, when it is combined with the different alkaline salts to the point of saturation, must form neutral salts of a somewhat different kind. That which is obtained with the *mineral alkali*, will indeed be like that of Seignette, but yet differ from it in this respect, that it will not contain any vegetable alkali. But that, which is produced from the pure tartareous acid and the common *vegetable alkali*, will be perfectly similar to the tartarized tartar, just now described. While, on the contrary, that which may be obtained with the *volatile alkali*, will differ from the tartareous ammoniac so far, that in its compo-

* It may be more properly denominated *Spodic Tartar*.

ſition there will be found no fixed alkali *. Theſe ſalts however have not as yet been farther examined with regard to their properties. In theſe combinations the following circumſtance is remarkable; that in the ſecond of them, if, after the point of ſaturation has been attained, ſtill more acid of tartar be added till the lixivium taſtes evidently ſour, a real regenerated tartar *(Cremor Tartari regeneratus)* is precipitated. A ſimilar reſult was obſerved by *Retz*, when in the ſame proportion he had combined cauſtic ſpirit of ſal ammoniac with acid of tartar, ſo that the acid was predominant; namely, a ſalt was ſeparated in ſmall irregular cryſtals, but which had a much ſourer taſte than the ordinary tartar. It did not deliqueſce in the air, and exhibited the ſame property of being diſſolved with much difficulty in water: he calls it *volatile cream of tartar*.

Relative to the neutral ſalts formed with the *oxaline acid*, or *acid of ſugar*, the following particulars are to be remarked. When this acid, diſſolved in warm water, is ſaturated with *mineral alkali*, it produces a neutral ſalt, which is eaſily diſſolved, and cryſtallized, and forms pretty large cryſtals which fall to powder when expoſed to heat. From theſe the acids of vitriol, nitre, ſalt, fluor, arſenic and phoſphorus ſeparate the oxaline acid, and unite with the alkaline ſalt in its ſtead. Calcareous earth, heavy earth and magneſia likewiſe decompoſe this ſalt, by uniting with the ſaccharine acid, and ſetting the alkali at liberty. The ſame effect alſo has the common vegetable alkali, which likewiſe unites with the acid of ſugar, inſtead of the mineral alkali, and diſengages the former. *Bergman* has given this ſalt the name of *Alkali minerale ſaccharatum* †.

The ſame acid exactly ſaturated with *vegetable alkali* is eaſily cryſtallized. In the lixivium, after the requiſite evaporation, pretty large foliated cryſtals were formed, which were eaſily diſſolved by water, but with greater difficulty in ſpirit of wine. Set in a warm place they fell to powder. The acids and earths, which have been mentioned before, decompoſed this ſalt in like manner as they did the other. Even fire alone expels the acid of ſugar from every ſubſtance with which it is combined. This neutral ſalt has obtained the name of

* This ſalt is, properly ſpeaking, the *Ammoniacal Tartar*: that mentioned in the preceding paragraph being better diſtinguiſhed by the title of *Tartarus Ammoniaco-ſpodicus*. Vide p. 48. [E]

† Which might however with more propriety be called *Oxalidicratium Natroſum*, or *Natrous Oxalidicrate*.

*Alkali*

*Alkali Vegetabile Saccharatum* †. No ſurer means than this ſalt has ever been known for the diſcovery of calcareous earth in water, in whatever manner it is combined in that fluid. For the acid of ſugar attracts calcareous earth very powerfully, and carries it away from every other acid, forming with it an earthy ſalt, very difficult of ſolution, which falls to the bottom in the form of a white powder. Though this effect proceeds likewiſe from the mere acid of ſugar by itſelf, it nevertheleſs takes place more rapidly in thoſe caſes where a double affinity acts; ſo that it can never deceive us.

One part of this acid, with ſix of ſtrong *cauſtic ſpirit of ſal ammoniac*, yielded, after a gentle evaporation, tetraedrous priſmatic cryſtals, which gave a red colour not only to the infuſion of litmus but likewiſe to the juice of violets, fell to powder a little ſlower in a warm place than the acid of ſugar itſelf, and loſt one ſixth of their weight. They were alſo eaſily diſſolved in water, but with great difficulty in ſpirit of wine. In diſtillation, a concrete volatile alkali firſt came over, then a ſmall portion of the volatile neutral ſalt itſelf. The coaly reſiduum manifeſtly ſhews that a decompoſition had taken place, and the concrete ſtate of the volatile alkali which made its appearance, proves, that at the ſame time ſome fixed air muſt have been diſengaged. This ſalt is, like the two preceding, decompoſed again by the fixed alkaline ſalts, and by the above mentioned acids and earths. It is called *Alkali volatile Saccharatum* †.

In Dr. *Lichtenſtein's* experiments, from the combination of the *acid* of *benzoe* with *mineral alkali* was produced a ſalt of eaſy ſolution, which formed ſhort, thin ſpiculæ, and did not deliqueſce in the air, but in ſome meaſure fell to powder in it. Its taſte was ſomewhat ſharp and pungent ‡. With fixed *vegetable alkali* a neutral ſalt was obtained, which alſo conſiſted of ſhort and thin ſpiculæ, united to each other by one of their extremities at acute angles, and thus had the appearance of light downy feathers. They quickly melted upon the tongue, had a ſaline, ſharp and pungent taſte, and attracted the moiſture of the air ſo as to deliqueſce in it §. With *volatile alkali* a ſalt was obtained, which cryſtallized with greater difficulty, had a ſharp, acid taſte, was eaſily diſſolved,

* Or rather *Oxalidicratium Spodicum*; or, for the ſake of greater brevity, *Oxalicratium Spodidicum*. [E]

† *Oxalidicratium Ammoniacum*, or *Ammoniacal Oxalidicrate*. [E]

‡ *Natrous Benzicrate*. [E]

§ *Spodic Benzicrate*.

and

and likewiſe attracted the moiſture of the air to deliqueſcence. The cryſtals in like manner reſembled little feathers, which adhered together *. All the three ſalts are decompoſed by mineral acids. According to Profeſſor *Leonhardi*, they likewiſe diſſolve in oils.

The animal *acid* of *beef-ſuet*, ſaturated with *mineral alkali*, produced, according to Profeſſor *Crell*, a ſalt, the figure of which was quadrangular, and for the moſt part compoſed of triangular acuminated pyramids. They formed together one entire cake of ſalt, upon which little ſeparate heaps of cryſtals were ſeen, that appeared to proceed from one common centre. In the air they contracted a white colour, and their taſte was like that of the cryſtallized Terra foliata Tartari. It had the appellation of *animo-mineral Salt* beſtowed upon it †.

The ſame acid, combined with *vegetable alkali*, yielded a ſalt reſembling the Terra foliata Tartari, and which, like that, on account of its brown colour, may alſo be purified by gentle fuſion and repeated ſolution, by which it acquires a white colour and a foliated form. It was however different in this, that it formed rectilinear tetraëdral cryſtals in the ſhape of daggers, and three lines in length. Its moſt remarkable property is this, that on being diſtilled by a naked fire, like foliated ſalt of tartar, it yields a mere empyreumatic ſpirit, which has no acid taſte, and leaves a coal with the fixed alkali in the reſiduum: a property, in which it exactly correſponds with the vegetable acids. In memory of its inventor, it might be called *Segner's* ‡ *Animal Tartar.*

Saturated with volatile alkali, the ſame ſalt, in almoſt the ſame degree of heat, which ſal ammoniac requires for its ſublimation, yielded a ſnow-white ſalt, of a ſtrong, ammoniacal, cooling taſte, though in ſome meaſure leſs ſharp than that of common ſal ammoniac. *Segner* gave it the name of *animal ammoniac*. This ſalt however muſt not be confounded with the phoſphoric ammoniac, which is alſo conſidered as an animal ammoniac §.

From the combination of the *acid of ants* with *mineral alkali*, ariſes a peculiar neutral ſalt, which is not much unlike the cryſtallizable foliated earth of tartar; has a ſaltiſh, bitter taſte, and is ſoluble in double its quantity of water. M. *Marggraf* united this acid with the *common vegetable alkali* to the point of ſatu-

* Ammoniacal Benzicrate. [E]

[† It ſhould be ſtiled perhaps, *Natrous Steatocrate.*

‡ Rather *Spodic Steatocrate.* [E]

§ *Ammoniacal Stateocrate.*

ration,

ration, and at length obtained oblong cryſtals from it, which however after ſome time deliqueſced in the air. When the whole ſaturated lixivium is evaporated to dryneſs, and diſtilled from a retort by a very briſk fire, a ſmall portion of a fluid acid is firſt obtained; and afterwards a trifling quantity of a liquid, which is more of an alkaline than of an ammoniacal nature. The reſiduum is in a carbonaceous ſtate, from which the alkali may again be elixated in water in a ſeparate and uncombined ſtate. Saturated with *volatile alkali*, this acid forms an ammoniacal liquor, which, on being diſtilled in a glaſs retort, comes over in the ſtate of an ammoniacal ſalt*, but does not form a ſolid and concrete ſublimate, and leaves nothing behind it but a ſmall portion of coal.

The ſecond kind of neutral ſalts conſiſts of the *earthy*. Under this denomination are compriſed thoſe combinations of neutral ſalts, in which the different acids are united with the various ſoluble kinds of earth.

Thus from the combination of *vitriolic acid* with *calcareous earth* an earthy neutral ſalt is produced, which is known by the name of *Selenite*. This compound is found ready formed by nature in earths and ſtones of the gypſeous kind, which are diſtinguiſhable from ſuch as are artificial, by a more intimate adheſion of the two parts, and by (what is the conſequence of this) a ſmaller degree of ſolubility in water. Native ſelenite is obtained by boiling down the purer kinds of gypſum after filtering the ſolution, and evaporating the water. The actual compoſition of it by means of art is effected by adding to diluted acid of vitriol pure calcareous earth till no farther efferveſcence enſues. The earth, which in this operation falls to the bottom, is the ſelenite that has been

* It ſhould have been noticed above, firſt, that the greateſt part of the Glauber's ſalt that is ſold, is obtained as an adventitious product in the ſal ammoniac manufactories, where the vitriolic ammoniac is decompoſed by the addition of ſea ſalt, the alkaline baſis of which, with vitriolic acid, forms Glauber's ſalt.

Secondly, with reſpect to the ſulphureous ſalt of *Stahl*, or Spodic Sulphurocrate, it muſt be obſerved, that this ſalt is likewiſe obtained by throwing vitriolic acid air into a ſolution of vegetable alkali.

This ſulphureous ſalt has a much ſtronger taſte than vitriolated tartar, and is much more ſoluble in water; it loſes the latter property however when it has been kept for a long time, and thus parted with the whole of its phlogiſton. When ſuperſaturated with ſulphureous acid, it does not cryſtallize, but remains a moiſt, concrete, ſaline maſs. This ſalt, before its phlogiſton is evaporated, detonates with nitre, and alkalizes it. According to *Bergman*, the cryſtals are hexagonal. Vide *Bergman* on *Elective Attractions*. Sect. 36. [D]

gene-

generated; of which the water that covers it ſtill contains as much as its nature will ſuffer it to take up. Indeed, when a much greater quantity of water is added, the whole may be diſſolved by boiling. It is likewiſe produced by pouring vitriolic acid into a ſolution of calcareous earth in nitrous or marine acid, till the liquor ceaſes to become turbid. Crude calcareous earth may alſo be converted into ſelenite by mixing it with ſulphur, and urging this mixture with a red heat in the open air. This combination is but very ſeldom made on purpoſe; but it is more frequently obtained on occaſion of other operations: in the preparation of the pure acid of tartar, for inſtance, and of the acid of bones, and in many other caſes beſides. According to *Beaumé*, quick-lime and lime-water, when combined with vitriolic acid, yield a more tranſparent ſelenite in larger cryſtals, which alſo was more ſoluble than another obtained from crude lime-ſtone: as it was alſo diſtinguiſhable, according to *Brandt* *, by being more eaſily converted into glaſs.

From the combination of vitriolic acid with *terra ponderoſa*, in all caſes, ariſes *Baro-ſelenite*, or regenerated *Heavy Spar*. This is effected as well immediately by a direct combination of both theſe bodies, as indirectly and occaſionally when either mere vitriolic acid, or elſe a vitriolic neutral ſalt, is poured into a ſolution of terra ponderoſa in the nitrous or marine acid. Heavy ſpar may be diſſolved by coction in concentrated vitriolic acid.

The combination of vitriolic acid with *Magneſia* produces *Epſom ſalt (Magneſia vitriolata* †, *Sal Ebſambenſe)*. This ſalt is of a bitter taſte, anſwering to its name ‡. In the ſhape of its cryſtals it reſembles Glauber's ſalt, and exhibits an equal degree of ſolubility in water, and likewiſe poſſeſſes the ſame purgative quality. It falls to powder indeed in the air, but not ſo quickly as that ſalt; and does not part with its acid in a violent fire. The ſolution of it in water is decompoſed by the alkaline ſalts, and the earth precipitated; which is alſo effected by lime-water and quick-lime. Fuſed with powdered charcoal, it will not yield a liver of ſulphur. This combination is met with native in great abundance. In many places it is found effloreſcent in a concrete ſaline form, of which

* According to *Bergman*, 100 parts of ſelenite contain 34 parts of calcareous earth deprived of its fixed air, 44 of acid, and 22 of water. [A]

† Potius *Vitriolum muriæciacum*.

‡ In German *Bitter Salz*, i. e. bitter ſalt. In Latin, Sal catharticus *amarus*.

the

the *Salt of the Alps*, which is frequently found in Switzerland in clefts of rocks, may ſerve as an inſtance: indeed the plaſtering of the clay-walls in that country often conſiſts of nothing elſe. But it is found in ſtill greater abundance in ſeveral mineral waters, which for this reaſon are called *Bitter Waters*; ſuch are thoſe of *Sedlitz*, *Seidſchutz*, *Egra*, and *Epſom*; from which, by mere evaporation, it is made fit for cryſtallization, but at the ſame time, by the continued agitation of the cryſtallizable lixivium, brought into the uſual cryſtalline form. This ſalt moreover is now made in the greateſt quantity, in many places in England, of the mother-ley of ſea-water, without any other addition ‡. Thoſe ſalts however, which are procured from mineral waters, are ſeldom any of them ſo pure as not to contain ſome other ſalts beſides. It may alſo be obtained in an artificial manner, after due evaporation, by diſſolving pure magneſia in vitriolic acid. A hundred parts of this ſalt conſiſt of about thirty parts of vitriolic acid, nineteen of magneſia deprived of its fixed air, and forty-eight of water of cryſtallization.

From the vitriolic acid and the *earth of alum*, when the acid is not perfectly ſaturated with the earth, is produced *alum*. Hence it is that it ſtill exhibits ſome veſtiges of a free, uncombined acid, and makes the infuſion of litmus red. In the cryſtallization of it, a great quantity of water is abſorbed by its cryſtals, the uſual form of which is octoëdral. In the fire it expands, and thereby loſes the water which it contained, and which is nearly one half of its weight; the reſiduum is called *burnt alum*. It is eaſily diſſolved in water, has a ſweetiſh aſtringent taſte, and may be uſed with advantage as a ſtyptic. The mutual proportion of its conſtituent parts is thus determined by *Bergman*: a hundred parts conſiſt of thirty-eight parts of vitriolic acid, eighteen of earth of alum deprived of its fixed air, and forty-four parts of water.

To prepare this ſalt in ſmall quantities from the above mentioned conſtituent parts, ſome pure earth of alum is to be put into any quantity (ad libitum) of diluted vitriolic acid, till a redundancy of acid is no longer diſcoverable by the taſte, and till the mixture has entirely the taſte of alum: upon which the lixivium is filtered and cryſtallized in a very moderately warm place.

‡ Dr. *Nehemiah Grew* firſt diſcovered the native magneſian (muriœcic) vitriol, or ſal catharticus amarus, in the Epſom waters, in the year 1675. But the artificial and improved method of obtaining it from the mere mother-water of ſea-ſalt was diſcovered by Dr. *Hoy* in the beginning of this century. Vide Phil, Tranſ. Vol. XXXII. pag. 348.

Under these circumstances this salt may be called *regenerated alum* *. Besides this method, it may also be directly prepared from clay, by thoroughly mixing one part of fine white clay, reduced to a fine powder, with one part and a half of oil of vitriol, in a retort, then expelling all the liquor from it again till the mass acquires a red heat; and after this, boiling, evaporating and crystallizing the residuum. Should there still be in it any redundant vitriolic acid, which would prevent the crystallization, alkali dissolved in water may be added by degrees, till a precipitation of the earth of alum is perceived to take place.

Nature, in her bounty, having previously combined its constituent parts together in different kinds of earth, this salt is obtained in the great by a mere artificial separation of these parts: they having been previously made fit for such separation by various kinds of preparations. The earths fit for this purpose, are called *ores of alum*, which however are very different as to their composition. Sometimes the matter of which they are composed is of an argillaceous nature, sometimes it consists of a brown asphaltic earth, at other times it is an unguinous, bituminous schistus or slate, at others a blackish schistous stone; at others again it consists in a composition of bitumen, mineral coal, and wood; and at others of a bituminous, brown, subterraneous wood; which latter kind, among others, is used in the alum manufactories of Hesse and of Minden in the Electorate of Hanover. But let their external appearance be what it will, clay and vitriolic must in every instance enter into their composition. When these aluminous ores possess but little bituminous matter, they have either a taste of alum immediately after being dug up, or else this taste manifests itself when they have been exposed to the air for some time, and have effloresced in consequence of its action upon them. If all this takes place on different occasions in the free and unconfined course of nature, before art has in the least contributed towards it, a *natural crystallized alum* is produced, as also a yellow, unguinous, soft, saline substance, called *Stone-butter*, which comes, like a stalactite, out of various aluminous schisti, but after a certain time grows white and hard in the air; from which also the waters, that contain alum, derive their origin. Those ores of alum, on the contrary, which contain more bituminous particles, as most of the aluminous schisti do, must be first roasted or thoroughly calcined, and then elixated several times. In many aluminous schisti of the latter kind, in which the bituminous, argillaceous base is intermixed with pyrites, it is to be presumed, that the compo-

* *Alumitic Vitriol.*

sition

fition of the alum is not accomplifhed previous to the combuftion of the fchifts, but rather in confequence and by means of the combuftion; by which the phlogifton is expelled from them, and the vitriolic acid then, and not before, combined with the foluble argillaceous earth.

The lixivium obtained from it cannot, in general, be directly boiled down to alum. It commonly ftill contains a redundant portion of vitriolic acid combined with ferruginous earth, which prevents the cryftallization. With a view to get rid of this, a proportional quantity of lixivium of wood-afhes, or of putrid urine, is added to the lixivium, till the ferruginous earth is all precipitated, and a white precipitate begins to appear. Far more advantageous however, with refpect to this purpofe, is *Bergman's* method of adding to fuch a lixivium one part of pure clay (which contains no iron or calcareous earth, and of which the quantity muft be determined by experience) and boiling this clay for a fhort time with it. In this manner the ferruginous earth is excluded, the acid remaining after the feparation charged with argillaceous earth, and at the fame time the quantity of alum increafed. When this object has been attained, the lixivium is boiled down to the point of cryftallization, and after it has depofited its impurities, poured into the veffels in which it is to be cryftallized. The firft impure cryftals are refined by a frefh folution in boiling water, upon which it forms large cryftals, and obtains the appellation of *common alum*. If the ores of alum contained too much iron, the alum will alfo contain a portion of this metal, and be of a yellow colour. To free it from this colour, is very difficult, and is alfo attended with too great expence. In fuch cafes, care muft be taken, 1. To throw away the mother-waters, which otherwife are again added to the frefh lixivia, as thefe former are moft contaminated with it. 2. To boil the aluminous lixivium afrefh for fome time with a clay which contains no iron. Befides this, the folution of an impure kind of alum like this, might for a certain time be expofed to the air, that the martial vitriol, which is found in it, may lofe its phlogiftic matter, after which its ferruginous earth alfo will by degrees fubfide to the bottom.

The *Roman* alum is diftinguifhable from the above mentioned common alum by a pale-red colour, and by the very fmall portion of iron which it contains, fo fmall indeed, that it is not worth mentioning. It is prepared near Tolfa in the vicinity of Civita Vecchia. The alum-ftone of that country is an indurated clay, which is quite white and thoroughly penetrated with vitriolic acid; and

alſo contains ſome gypſum, which, according to *Ferber*, ſettles in the wooden troughs that convey the liquor to the coolers. Theſe ſtones, after being calcined in furnaces of a peculiar conſtruction, are elixated, and the lixivium is boiled down. But before the lixivium is ſuffered to run into the coolers, it is ſtopped for a ſhort time in the troughs, that it may depoſe a reddiſh ſelenite there. During the boiling, ſome urine and lime ought to be added to the lixivium. The alum cryſtallizes in the coolers, which are made of wood, for the greateſt part of a white colour, though ſome cryſtals are of a reddiſh hue. The redneſs of it proceeds from a very fine red earth, which cannot eaſily be ſeparated from it.

As the acid in the alum is not perfectly ſaturated with the aluminous earth, it is eaſy to conceive, that by a perfect ſaturation its nature muſt be very much altered. Therefore, when *Beaumé* boiled four ounces of earth of alum, and two ounces of alum with a ſufficient quantity of water, the alum was ſaturated with the earth to ſuch a degree, that all its taſte was loſt, and that the water taſted only like a hard ſpring water. After filtration and evaporation, in the ſpace of a few months ſome ſcaly, micaceous cryſtals were formed in it, which were of very difficult ſolution in water, and that in a ſmall quantity only.

If half an ounce of alum be boiled in water with half a drachm of lime ſlaked by expoſure to the air, according to Dr. *Sieffert*, *cubical cryſtals of alum* are obtained after proper evaporation.

From the union of *nitrous acid* with *calcareous earth* ariſes *calcareous nitre*. Even with the moſt perfect ſaturation of both theſe its conſtituent parts, the ſolution may, it is true, beevaporated to the conſiſtence of a ſyrup, in which alſo, after a certain time, ſome cryſtals will be formed; but theſe, together with the whole inſpiſſated maſs, will ſoon deliqueſce again in the air. Thence it is eaſy to conceive that the nitrous efflorеſcence on the earth-walls of the ſalt-petre works cannot poſſibly conſiſt of this combination. In a violent fire the nitrous acid flies off, or to ſpeak more properly, is decompoſed and deſtroyed, and what remains behind is the *phoſphorus* of *Baldwin*. There is no difference to be perceived between the ſalt here ſpoken of, and a ſolution of quick-lime in this acid, if care be taken that the acid be perfectly ſaturated with the lime. This point is eaſily miſſed, becauſe it cannot be directly aſcertained by external marks, and the ſolution, though perfectly ſaturated, is ſtill capable of taking up a portion of quick-lime, as redundant.

With *terra ponderofa* this acid forms a falt, which is called *nitrous Barytes*, (terra ponderofa nitrata) *. It forms hard, folid cryftals, which do not deliquefce when expofed to the air, are very heavy, of a bitter tafte, and of difficult folution in water. In a red heat, the nitrous acid is decompofed or deftroyed, and nothing left but the terra ponderofa in a cauftic ftate.

The very fame acid combined with *magnefia*, yields a falt, after evaporation, which concretes into tetraëdral, prifmatic, fpathous cryftals with truncated apices; is of an acrid and very bitter tafte, and eafily deliquefces again when expofed to the air †. If a piece of paper be fteeped in this folution, and afterwards dried, it will burn with a green flame. In the folution of this falt in fpirit of wine, this change of colour is not feen. By fire, all the nitrous acid is expelled again.

From the *earth of alum* and this acid arifes a peculiar earthy falt, which after evaporation cannot be cryftallized either by itfelf, or by the addition of alkali; a thick gummy mafs only remaining, which, on farther evaporation, lofes part of its acid, and, when expofed to a red heat, parts with the whole ‡. *Wenzel* thinks this combination of alum might be advantageoufly ufed in dying, as the colours of the ftuff would be rendered brighter by this than by the common alum.

The *marine acid* likewife, with the different earths, produces various combinations of neutral falts, on occafion of which feveral circumftances occur worthy of remark. When it is faturated with *calcareous earth*, a liquor is obtained, which cannot be cryftallized after evaporation. This earthy falt, when evaporated to drynefs, very improperly bears the name of *fixed fal ammoniac*; and in this ftate becomes fufible in a fierce fire, like water, without letting go the leaft part of its acid, and afterwards deliquefces in the open air, as rapidly as it did before. This compound is with greater propriety called *calcareous muria*. In other refpects it is precifely the fame thing, whether thefe conftituent parts be pofely combined together in their pure, diffevered ftate, or be with any other view accidentally brought together from their combination with other fubftances. For this reafon, the refiduum, that is left behind after the diftillation of the cauftic fpirit of fal ammoniac, when diffufed in water, evaporated, and fufed over the fire, is in no refpect whatever different from the falt above-mentioned.

* Rather *Barytic Nitre*. † This falt may be called *Muriacic Nitre*. ‡ *Alumitic Nitre*.

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In this ſtate it exhibits the *phoſphorus* of *Homberg*. Neither indeed does the reſiduum, which is obtained in conſequence of the ſeparation of volatile alkali, in a concrete ſtate, from ſal ammoniac by chalk, differ in the main from theſe. If this ſalt be ſuffered to deliqueſce in the air, the *oleum calcis* is generated, with which the *miraculum chemicum* may be wrought; viz. when this liquor is mixed with a ſtrong ſolution of common alkali, the two liquids will inſtantly produce a ſolid earthy body, which may be formed into a ball with the hands.

From the union of this acid with *terra ponderoſa*, an earthy ſalt, is obtained, called *Muria Barytica* (terra ponderoſa ſalita *) which does not part with its acid again in the fire. It forms pretty large foliated cryſtals, which remain dry when expoſed to the air, have a bitter taſte, and require a conſiderable quantity of water for their ſolution, and likewiſe diſſolve in ſpirit of wine. The ſolution is decompoſed as well by the mere vitriolic acid ſeparately, as by any other neutral ſalts that contain it. For this reaſon it is uſed in preference to any other ſubſtance for the purpoſe of detecting the acid of vitriol in different ſubſtances. The fluor- and ſaccharine acids precipitate the earth from it, at the ſame time uniting with the latter.

From the marine acid and *magneſia alba* ariſes, after ſaturation and evaporation, an earthy ſalt, vhich does not cryſtallize, and therefore muſt be only evaporated to dryneſs; deliqueſces again on expoſure to the air; in a fierce fire however parts with its acid again, and in other reſpects is in its liquid ſtate very like the mother-water of common ſalt. It bears the name of *Muriatic Magneſia* † (Magneſia ſalita).

With the *earth of alum* this acid produces *muriatic alum* ‡, which conſiſts merely of an uncryſtallizable ſaline maſs, and in its external appearance, and other qualities, reſembles in every reſpect that which is obtained from the nitrous acid and this earth. The acid is by a fierce fire again expelled from it.

The *fluor acid*, ſuch as it hitherto has been obtained in glaſs-veſſels, diſſolved *calcareous earth*, and continued to be clear till the acid was ſaturated, when all the diſſolved earth, that was united with the acid, ſeparated from the maſs, of which one part fell to the bottom, another part was converted into a jelly with the liquor, on expoſure to the air, and the other part was regenerated fluor-ſpar. Saturated with *terra ponderoſa*, the fluor acid yields a pulverulent ſalt of difficult

* Better ſtyled *Barytic Muria*.

† It ſhould rather be called *Muriatic Muria*. ‡ *Alumitic Muria*.

ſolution,

ſolution, which, by reaſon of the greater affinity of this acid with the calcareous earth, may be decompoſed by being mixed with lime-water; as it likewiſe may on being mixed with vitriolic acid, on account of the greater affinity of this latter with the terra ponderoſa. This may be called *Terra ponderoſa fluorata* *. In an adventitious way, this combination takes place, in conſequence of mixing the ſolution of terra ponderoſa in nitrous or marine acid with the fluor acid. In the ſame manner alſo was *magneſia* diſſolved, but part fell to the bottom directly, combined with the fluor acid, when the remaining maſs became gelatinous as in the former caſe. With *earth of alum*, this acid made a ſweet ſolution, which could not be brought to cryſtallize. In the union of the pure fluor acid, and diſſolved glaſs or *ſiliceous earth*, conſiſts the whole of that ſubſtance, which is expelled from the fluor-ſpar by the vitriolic acid †. Eſpecially when as much ſiliceous earth as poſſible has been diſſolved in it afterwards.

By the combination of *ſedative ſalt* with *calcareous earth* no ſalt is produced that is ſoluble in water; but, on the contrary, they both fall to the bottom of the veſſel in the form of a powder ‡. The affinity of this acid to *terra ponderoſa* is ſtill unknown. With *magneſia*, ariſes, after evaporation, a clammy maſs, which is ſtriped with innumerable rays, going from the circumference to the centre, where various ſhining points are to be ſeen in the form of little cryſtals §. A piece of paper dipped in this ſolution ſeemed to burn with a darker green than the pure ſedative ſalt is wont to produce; which ſhews, that the magneſia contributes ſometimes ſomething to this, as indeed it likewiſe produces this phenomenon of itſelf, when diſſolved in nitrous acid. If lime water be added to this ſolution, it becomes turbid, and even milky, which is a farther proof, that theſe two earths are not the ſame, becauſe they ſhew a different affinity to one and the ſame menſtruum. The union of ſedative ſalt with *earth of alum* ‖ may beſt be accompliſhed in the following method; viz. by adding a ſolution of borax to a ſolution of alum, by which means the ſedative ſalt, and the earth of alum are ſet at liberty, and then act upon each other. The liquor, ſtrained off from it after evaporation, leaves a viſcid, adheſive, and very aſtringent maſs, which conſiſts of the two parts above-mentioned.

* Or rather, *Fluoricratium Baryticum*, Barytic Fluoricrate.

† This may be called *Siliceous Fluoricrate*.

‡ *Calcareous Borax*. § *Muriacic Borax*. ‖ *Alumitic Borax*.

Dephlo-

*Dephlogiſticated arſenic* may be united in the following manner to *calcareous earth*; 1. By direct and immediate ſolution in this acid diluted: 2. By mixing this acid with lime-water, when it firſt precipitates the calcareous earth, which however, by the addition of acid, is diſſolved again, in conſequence of which ſmall cryſtals are produced; from a ſolution made of theſe, gypſum is precipitated by means of vitriolic acid. 3. The ſolutions of calcareous earth in the nitrous, marine, and acetous acids may likewiſe be precipitated by means of arſenical neutral ſalts; on which occaſion the above-mentioned union alſo is made. 4. If water, impregnated with arſenic, be digeſted with lime that has fallen to pieces in the air, a ſolution of the latter is obtained, that, after evaporation, forms an earthy pellicle which does not deliqueſce, expands and ſwells when laid on red hot coals, and emitting an arſenical vapour, leaves the calcareous earth behind *.

When the liquid *acid of arſenic* is ſaturated with *terra ponderoſa* †, or a ſolution of terra ponderoſa, in the nitrous, marine, or acetous acids, is mixed with a ſolution of arſenical neutral ſalt; in all theſe caſes the combination firſt indicated is accompliſhed forming a ſalt of difficult ſolution. The vitriolic acid however takes the terra ponderoſa again from the acid of arſenic.

*Magneſia* alſo may, according to *Scheele*, be eaſily diſſolved by this acid: but nothing ariſes from this union except an uncryſtallizable jelly. The arſenical neutral ſalts likewiſe, from the ſolution of this earth in the different acids, throw down a precipitate, which is ſoluble again in acids, but not in water.

In like manner too, according to *Scheele*, the *earth of alum* may, directly after its precipitation from alum by alkali, and while it is ſtill wet, be eaſily diſſolved by deplogiſticated arſenic ‡. Otherwiſe the ſame combination may alſo be effected by precipitation from the ſolution of this earth in diſtilled vinegar, but not from a ſimilar ſolution in mineral acids.

Of the combination of the *Acid of Molybdæna* with chalk, magneſia, and earth of alum, nothing farther is known than that by expulſion of the aerial acid it unites with them, and forms neutral ſalts of difficult ſolution. The *Tungſtenic* or *Barolithic Acid*, after having been ſaturated with volatile alkali, precipitates the lime from *calcareous nitre*, forming with the lime a ſalt of difficult ſolution. This combination alſo takes place when the tungſtenic acid, in a liquid ſtate, is boiled with lime-water §. The ſolution of heavy earth

* *Calcareous Arſenicrate.* † *Barytic Arſenicrate.* ‡ *Alumitic Arſenicrate.*
§ *Calcareous Barylithricrate.*

in acetous acid is alſo decompoſed by the latter, and an inſoluble earthy ſalt produced by it.

The *phoſphoric acid*, combined with *calcareous earth*, forms a ſaline-earthy body, of which conſiſts the pure earth of bones, and which is almoſt inſoluble in water, becauſe this earth only abſorbs the acid, and remains for the greateſt part inſoluble; at the ſame time however part of it is obtained in a diſſolved ſtate*. When the ſolution of the *terra ponderoſa* in marine acid is precipitated by phoſphoric acid, the precipitate conſiſts of *phoſphoric Barytes* (terra ponderoſa phoſphorata †). *Magneſia* was indeed perfectly diſſolved by this acid; but the liquor ſoon afterwards became thick, and at the ſame time a conſiderable number of ſmall cryſtals ſeparated from it ‡. When upon this it was boiled with ſome water, and ſeparated by filtration from the powder, which it had depoſited, on the evaporation being continued, ſmall, ſolid cryſtals again fell to the bottom. At laſt there remained a ſaline maſs reſembling gum arabic, which became greaſy on expoſure to the air, and like the precipitated cryſtals was, when ſubmitted to the blow-pipe, melted down to a ſmall, white, tranſparent ball. Almoſt the ſame phenomena are obſerved on uniting this acid with the *earth of alum* §. One part of it actually diſſolves; the reſt remains combined with the phoſphoric acid, at the bottom of the veſſel, like a ſaline powder. During the evaporation of the clear ſolution, a ſandy powder falls to the bottom, and at laſt a matter like gum remains, which likewiſe being placed upon the coals, melts together into one maſs, and forms a white tranſparent glaſs.

It is remarkable of the preceding combinations, that calcareous earth and magneſia cannot be entirely deprived of all their aerial acid (or fixed air) by the acid of phoſphorus; as the ſaline powders, which are formed during the ſolution, ſtill efferveſce with other acids. This alſo is the caſe in ſeveral other inſtances; and proves, in my opinion, that every acid does not penetrate to the ſame depth into thoſe bodies with which it is to be united, and that conſequently all acids cannot expel the aerial acid from ſuch bodies in the ſame quantity. A trial ought farther to be made, whether phoſphorus can be made with phlogiſton from the vitrified earthy ſalts above-mentioned.

The *acid of amber* diſſolves *calcareous earth* with great eaſe, on which occaſion its acid taſte is loſt, and a bitter taſte, on the other hand, takes place. In the ſolution are formed with great rapidity long ſpicular cryſtals, which are

* *Calcareous Photocrate.* † Or rather *Barytic Photocrate.* ‡ *Muriatic Photocrate.*
§ *Alumitic Photocrate.*

with great difficulty to be rediſſolved in water. A combination of this acid with *terra ponderoſa* is as yet unknown. Salt of amber, ſaturated with *magneſia*, yielded to *Wenzel* a gum-like maſs only. But from a ſolution of *earth of alum* in the ſame acid, he obtained cryſtals, for the greateſt part, of a priſmatic form *.

Of the union of *acid of lemons* with *calcareous earth*, *terra ponderoſa*, and *magneſia*, it is remarkable, that, as long as this acid is not perfectly ſaturated with the earth, the ſolution remains limpid: but in proportion as the liquor approaches to ſaturation, it becomes turbid, and when it is ſaturated, the earthy ſalt falls to the bottom as a precipitate of difficult ſolution in water, which can only be rediſſolved by a redundant quantity of acid of lemons. Theſe ſolutions as well as the acid of lemons ſaturated with *earth of alum*, leave behind them, after evaporation, a gummy maſs †.

From the pure *acetous acid*, after it has been ſaturated with *calcareous earth*, and gently evaporated, are obtained ſlender cryſtals, which remain dry when expoſed to the air, the acid of which however is deſtroyed by expoſure to the fire, and nothing but the mere calcareous earth remains. From the *terra ponderoſa*, diſſolved in acetous acid, *Bergman* extracted a deliqueſcent uncryſtallizable ſaline maſs. A ſolution of *magneſia* in this acid forms no cryſtals, but, on evaporation, leaves only a gummy ſaline maſs, which deliqueſces again on expoſure to the air, and which, like the former, in the fire parts again with all its acid. The *earth of alum* is alſo diſſolved by this acid, though in a ſmall quantity only. But the ſolution forms no cryſtals after evaporation; but, after having been evaporated to dryneſs, leaves a maſs of ſalt, which does not deliqueſce on expoſure to the air; and, like the two former, loſes its acid in the fire ‡. No attempt has yet been made to prepare the earthy neutral ſalts from the *acid of wood.*

From the union of the *acid of ſugar* with *calcareous earth* ariſes an earthy ſalt of difficult ſolution in water, called by *Bergman*, *Calx Saccharata* §. A hundred parts of pure tranſparent *calcareous ſpar* are abſorbed by eighty-two parts of *acid of ſugar*. Theſe two ſubſtances however cannot be well united in a direct way, becauſe the acid is prevented from penetrating deep by the ſaturated cruſt that is generated upon the ſurface of this ſpar. The eaſieſt way of effecting this combination is by precipitating calcareous earth from its ſolution in nitrous acid,

* *Calcareous*, *murioecic* and *alumitic Electrocrates.*

† *Calcareous*, *barytic*, *murioecic* and *alumitic Citrocrates.*

‡ *Calcareous*, *barytic*, *murioecic* and *alumitic Oxycrates.*

§ Better denominated *calcareous Oxalidicrate*: the acid of ſugar, and that of the *Oxalis* or Wood-ſorrel, being now known to be exactly one and the ſame acid.

in

in the form of a white powder, by means of the acid of fugar. From 100 parts of diffolved calcareous earth, are obtained 119 parts of this compound, of which about 72 are foon precipitated; but the remaining 47 do not appear till the liquor is evaporated. When from this the air, that has efcaped during the combination, is deducted, it will appear that a hundred parts confift of forty-eight parts of acid of fugar, forty-fix of quick-lime, and fix of water.

When the faccharine (or oxaline) acid is combined with *terra ponderofa*, there is an almoft immediate precipitation of tranfparent angular cryftals, becaufe they are of difficult folution in water*. Thefe, if they are boiled in diftilled water, fall to powder; but on cooling the liquor, the portion that is diffolved concretes again into cryftals containing a redundant acid; for this compound never cryftallizes, unlefs the acid be predominant. Now, boiling water takes the fuperabundant acid from the greateft part, and therefore renders it infoluble. They alfo precipitate calcareous earth from its different folutions. When put into a folution of cauftic vegetable alkali, they are covered with an opaque cruft, and at length fall to powder; while the alkali remains united with the acid of fugar.

This acid likewife diffolves *Magnefia*, and in like manner forms with it an earthy neutral falt in the form of a white earth, which, if the acid in it be redundant, may be diffolved in fpirit of wine. In two parts of it are found fixty-five of acid and water. This falt is decompofed by the fluor acid, as alfo by calcareous earth, and terra ponderofa. Pure magnefia, on the other hand, takes the faccharine acid from alkaline falts †.

Moreover thirty-five parts of acid of fugar take up, by digeftion, forty-two parts of well-edulcorated *earth of alum*. The folution, on evaporation, forms no cryftals, but merely a yellowifh, pellucid mafs of a fweet yet aftringent tafte. This when dry, deliquefces in the air, and increafes two thirds in weight. It reddens tincture of Litmus, but not fyrup of violets. It diffolves fparingly in fpirit of wine. It fwells in the fire, and in a red heat parts with its acid; the earth is left of a brown colour. A hundred parts contain about forty-four of earth, and fifty-fix of acid and water. The vitriolic, nitrous, and marine acids, the alkaline falts, calcareous earth, terra ponderofa and magnefia decompofe *faccharated clay* ‡. Iron alfo caufes a feparation in this falt, and falls to the bottom united with the acid.

* *Barytic Oxalidicrate.* † *Muriecic Oxalidicrate.* ‡ Or *Alumitic Oxalidicrate.*

The pure *acid of Tartar* likewife has a great affinity to *calcareous earth*. From this combination arifes a mafs of difficult folution in water, which has merely an earthy tafte, and confifts of very minute fpicular cryftals, the formation of which cannot be perceived before they are in a concrete ftate. This falt may be aptly denominated *Calcareous Tartar* (calx tartarifata, Tartarus calcareus), though by fome it has very improperly been called Tartareous Selenite. On being calcined by an open fire, this mafs expands to four or five times its bulk, and fwells like tartar. At length all the acid is burned and deftroyed, and nothing remains of it but the burned calcareous earth, with the coaly parts of the tartareous acid. The fame union likewife takes place, when cryftals of tartar are boiled with chalk, or any other calcareous earth. With the *terra ponderofa* this acid produces a falt, which is of eafier folution in water, and may be called *Barytic Tartar* (terra ponderofa tartarifata). It unites alfo with *Magnefia* * (*Magnefia tartarifata)*, and keeps it in the folution as long as it is not perfectly faturated with it. During evaporation, a falt fubfides to the the bottom of the veffel, in polygonous pellucid grains, which is with difficulty diffolved by fpirit of wine. *Via humida*, its union is deftroyed again by the fluor, faccharine, phofphoric, vitriolic, nitrous and marine acids. In the fire it fufes, fwells and expands, is partly converted into coal, the acid is confumed, and leaves the mere magnefia behind. *Earth of Alum*, recently precipitated, is diffolved by this acid; the liquor has a very aftringent tafte, and, on being evaporated, forms a gum-like mafs: (Terra Aluminis tartarizata †).

The *acid of Benzoe* diffolves *calcareous earth*; from which combination arifes a limpid folution that has very little of the faline, but, on the other hand, an agreeable and balfamic tafte, and forms fhining, white, feathered, fpicular cryftals; from which however the acid of benzoe may be feparated again by the nitrous or marine acid. Its affinity with *terra ponderofa* is ftill unknown. Saturated with *magnefia*, it produces neutral falt, which in like manner forms fmall feathered cryftals, that are foluble in water, and have a bitter, acrid tafte. It unites with *earth of alum*, that has been recently precipitated, and is ftill damp, and forms a falt which has fomewhat of an aftringent tafte ‡.

The *animal acid of fat*, after being faturated with *calcareous earth* and duly evaporated, yielded brown cryftals. The fame falt was obtained by Profeffor

* And may be called *Murioecic Tartar*.

† Or, *Tartarus Alumiticus*. Alumitic Tartar.

‡ *Calcareous*, *murioecic* and *alumitic Benzierates*.

*Crell*,

*Crell*, by mixing ſuet with quick-lime, diſtilling the maſs to dryneſs, and boiling the reſiduum up with water; which reſiduum, after being diſſolved and evaporated afreſh, formed cryſtals of a perfect hexagonal figure, and terminated by a plane ſurface. They were of an acrid, ſaltiſh taſte, did not deliqueſce on the air, and were eaſily and copiouſly, diſſolved in water. Profeſſor *Crell* thinks, that they might be called *animal calcareous ſalt* *. The affinity of this ſalt with *terra ponderoſa* is not yet known. *Magneſia* likewiſe entered into an union with this acid; but the lixivium, after it had been evaporated till a pellicle appeared, would not cryſtallize; but on the evaporation being continued, formed pellicles of ſalt only, which were not cryſtalline, and deliqueſced again in the air, and alſo had a bitteriſh taſte. The greateſt part of this ſalt was only inſpiſſated, ſo as to form a gum-like maſs. This compound may be called *Animal Magneſia* †. The *earth of alum* likewiſe combined with this acid; but chiefly, whilſt it was ſtill moiſt, and of the conſiſtence of pap, as it is juſt after the precipitation before the drying, though again more than the half of this was ſeparated from the ſolution. The filtered liquor had an auſtere, aſtringent taſte, and did not form any regular cryſtals. This combination exhibits a kind of *animal alum* ‡.

Laſtly, the *acid of ants*, ſaturated with *calcareous earth*, forms a ſalt in long cryſtals, which do not deliqueſce on expoſure to the air. With *terra ponderoſa*, this acid produces cryſtals in the form of aigrettes, which are bitter, non-deliqueſcent, ſoluble in four times its quantity of water, but which were not acted upon by ſpirit of wine. Combined with magneſia, ſmall ſolid cubical cryſtals ariſe from it, which have no peculiar taſte, are of difficult ſolution in water, do not fuſe, but fall to powder, when placed upon red-hot coals. But from this ſame acid and the *earth of alum* ariſes a ſalt, which does not cryſtallize, but becomes viſcid and greaſy on expoſure to the air §.

The *alkaline earthy ſalts* for the moſt part conſiſt of an imperfect and mutable combination. The *vegetable fixed alkali* can diſſolve but a very ſmall portion of *calcareous earth*, even by being fuſed upon the fire. Of the *terra ponderoſa*, the affinity is not known. *Magneſia* alſo, fuſed with a quadruple portion of alkali, is almoſt inſoluble in water. If one part of *earth of alum* be mixed with four

* A more proper appellation would be that of *Calcareous Steatocrate* (Steatocratium Calcareum).

† Or rather *Murioecic Steatocrate.*

‡ More properly called *Alumitic Steatocrate.*

§ *Calcareous, barytic* and *Alumitic Myrmecicrate.*

parts

parts of purified fixed alkali, and fufed by a very brifk fire, and this faline mafs be diffolved in diftilled water, a real alkaline folution of earth of alum is obtained, from which the earth may be precipitated by acids. It alfo foon precipitates of itfelf from the folution. But when one part of *powdered flints* is mixed with four parts of purified fixed alkali, and poured into a capacious crucible, and fufed by a very brifk fire, the flints are gradually diffolved, with great effervefcence and the production of froth; when this at length ceafes, and the mafs in the crucible fufes quietly, it is poured on an iron plate made warm. When cold, it is tranfparent, like glafs; but diffolves entirely in a fmall quantity of water. It alfo deliquefces of itfelf in a moift air, and is thereby converted to a cauftic liquor, which bears the name of *Liquor of Flints* (Liquor Silicum). *

We now come to the third kind of neutral falts, which are called *Metallic neutral Salts*. By this expreffion, we mean thofe faline fubftances in which an acid has been perfectly faturated with a metallic body, inftead of an alkaline falt, or an earth, from which arife fuch compounds as ftill poffefs faline properties, among which many have alfo a perfect faline appearance, and which differ from each other, partly in the nature of the acid, and partly in that of the metallic body.

The *Metal* of the *Lapis ponderofus*, or *Tungften*, would not unite with *vitriolic acid*. For the purpofe of effecting the combination of *manganefe* with this acid, one part of manganefe reduced to a fine powder, is mixed with two of concentrated vitriolic acid, and either digefted for fome time, or all the liquor is expelled from it, by diftilling it to drynefs in a retort. In both cafes the mafs is at laft diluted with water, and filtered. Upon which, in the firft cafe, a deep red, in the other, a pale reddifh folution is obtained, which after gentle evaporation, cryftallizes to a fine rofe-coloured falt, the figure of which is fparry, or refembles a parallelopipedon. It is called *Vitriol of Manganefe* (Vitriolum Magnefii) its tafte is very much like that of the fal catharticus amarus. This falt is alfo very apt to fall to powder on expofure to the air.

The *vitriol of red cobalt*, which certainly was firft obferved by *Lehmann*, is, according M. *Buchholz*, prepared in the following manner from *vitriolic acid* and the black dufty cobalt of *Saalfeld*, which blackens the fingers on being

* Experiments on the combination of different earths with vegetable alkali have been made by M. *Achard*. Vid. *Chemical Annals*, 1785, Vol. I. pag. 131 & feqq. [A]

rubbed between them, and ſhines, and is a very pure ſort of it. Half an ounce of this cobalt, and two ounces of oil of vitriol diluted with ſix ounces of water, are mixed together in a glaſs, and expoſed to a gentle heat. The combination of cobalt with vitriolic acid, is effected ſtill better by mixing one part of cobalt, reduced to a fine powder, with from two to three parts of concentrated vitriolic acid, and digeſting them together twenty-four hours, then diluting the ſolution with water, and filtering it. The cobalt of Saalfeld is preferable only on account of its purity. It yielded a red ſolution, which after undergoing ſufficient digeſtion, was decanted off; and afterwards poured upon the remaining black powder of cobalt. It recovered its red colour again, after it had been heated in the glaſs to the boiling point. Afterwards this ſecond ſolution was added to the firſt, and evaporated. As ſoon as a pellicle appeared upon it, it was put by in the cellar, where, after a lapſe of twenty-four hours, a conſiderable quantity of fine red vitriol had ſettled in ſmall cryſtals, on the ſides and bottom of the veſſel. The deep red liquor which ſtood upon it, was decanted off into another glaſs, and evaporated again. But it had hardly become thoroughly warm, before another ſaline pellicle appeared, for which reaſon it was immediately put into the cellar, where, on the ſubſequent day, it was found to have been entirely coagulated, ſo as to form a red ſhining lump. The glaſs being warmed a little, and inclined on one ſide, the red, glittering pellucid lump, which, in its external appearance, reſembled an animal jelly, ſeparated from the red vitriol that lay underneath it.

The combination of the *vitriolic acid* with *arſenic*, for the production of *vitriol of arſenic*, is effected either by digeſting one part of it with two parts of concentrated acid of vitriol, and diluting this ſolution with water; then filtering, evaporating and cryſtallizing it, which forms pyramidal, pellucid, ſhining, yellowiſh cryſtals. Or elſe the arſenic may be prepared for ſolution, by diſſolving it in three parts of deliquiated ſalt of tartar, and precipitating it from this again by vitriolic acid. The precipitate, after being edulcorated, is then covered with three parts of concentrated vitriolic acid, and kept in digeſtion for ſeveral days; after which the whole maſs is at length concreted to a lump of ſalt, which conſiſts of oblong cryſtals, converging from the ſides towards the centre of the glaſs.

From this acid and *nickel* is generated vitriol of *nickel*. Crude nickel neceſſarily requires concentrated acid of vitriol. But if the nickel is in a calcined

ſtate,

ſtate, it is eaſily diſſolved by diluted vitriolic acid, and forms green cryſtals, which exhibit an alum-like decaëdral flattened ſalt, with truncated extremities.

*Vitriol of antimony* is obtained by diſſolving regulus of antimony in oil of vitriol, in a gentle heat. The ſolution, the inſtant it is put into a cold place, will concrete into cryſtals, which are liquefiable with a low degree of heat.

The combination of the vitriolic acid with zinc, is effected already to our hands, by nature herſelf, as is proved by the method uſed for obtaining the *vitriol of zinc*, known alſo by the name of *white vitriol*. This is prepared at *Goſslar* only, by roaſting the ſilver ore of *Rammelſberg* in the ſame diſtrict, and pouring it out while it is hot, into large troughs, where it is extinguiſhed in water. The lixivium obtained by this means, is evaporated to the point of cryſtallization in leaden pans, and put by in wooden veſſels, during ſeveral weeks, in order to cryſtallize undiſturbed. The cryſtallized white vitriol is then thrown into a copper-pan, and fuſed, when it has the appearance of milk; upon which it is ſkimmed, poured out into ſquare boxes, and ſtirred with wooden ſpattles, till it is quite cold. By this means it acquires a looſe ſpongy texture, and a white colour, and after ſome time arrives at the requiſite degree of ſolidity, ſo that it has then the appearance of refined ſugar, in ſmall cryſtals. Sometimes the white vitriol ſtill contains iron and copper, of which it may be freed by boiling the lixivium up with zinc. The artificial combination of this acid in its dilute ſtate, with zinc, is made without any difficulty, and cryſtallizes, after evaporation, in quadrangular columns, with quadrangular extremities *. Upon *biſmuth*, the acid of vitriol acts with great difficulty, and but little.

When from one part of quickſilver, one and a half, or two parts of oil of vitriol are diſtilled to dryneſs, and the reſiduum is triturated with water, part of the mercury combined with the vitriolic acid is taken up by the water, and by evaporation is obtained the *vitriol of mercury*. When this is ſuffered to deliqueſce, the *oil of mercury* (oleum mercurii) is produced. This acid does not diſſolve *platina*.

From the union of vitriolic acid with iron, proceeds *vitriol of iron* (vitriolum martis). Nature makes this combination in ſuch quantity, that nothing is left

* The particular conſtituent principle of white vitriol was not known till the year 1735. At this period, however, *Brand* in *Sweden*, and *Hellot* in *France*, diſcovered that its real conſtituent parts were zinc and vitriolic acid. [A]

for

for art to do but to ſeparate and purify it. The pyrites, which conſiſt chiefly of ſulphur and iron, are for a certain time expoſed to the open air, till they are entirely fallen to powder, to forward which proceſs, they may likewiſe be moiſtened with water. The pyrites is then elixated with water, as long as the lixivium continues to be rendered turbid by alkali; after which it is boiled down till a pellicle appears upon it, and is cryſtallized. When the pyrites contains a conſiderable portion of ſulphur, the ſulphur is firſt expelled from it in the ſulphur-works, and the reſt expoſed to the air, in order to undergo a farther decompoſition. Sometimes ſuch a heat is generated on this occaſion, that the heap breaks out into flames. The pyrites thus decompoſed is, in the laſt place, elixated, boiled down, and cryſtallized. Moſt pyrites, together with iron, contain copper, zinc and argillaceous earth, whence alſo native vitriol is commonly contaminated with ſuch ſubſtances. During the boiling, the copper, and the argillaceous earth of alum, may be precipitated from the lixivium, by an addition of iron, which however has no efficacy with reſpect to the zinc. When this elixation of the pyrites is performed, purſuant to the ſpontaneous courſe of nature, in the earth itſelf, chalybeate ſprings, and even native vitriol ariſe from it.

*Vitriol of iron* (or *copperas)* is prepared by art, in the following ways: Firſt, by mixing, in imitation of nature, equal parts of filings of iron and ſulphur, then moiſtening the mixture with water, and about a week after, elixating and evaporating it: Secondly, by pouring upon one ounce of pure iron, for which uſe nails broken to pieces are beſt, two ounces of oil of vitriol diluted with ſixteen of water, which acts very briſkly upon the iron, and diſſolves it with efferveſcence and heat. On this occaſion a great quantity of inflammable air is generated, which has a peculiar and very offenſive ſmell. The liquor after being filtered, is evaporated in an iron veſſel, till a pellicle makes its appearance, and is ſet by in a cool place for cryſtallization, where it forms green cryſtals of a rhomboidal figure. Formerly, this preparation was called *Salt of Steel* (Sal martis Riverii). In the cryſtallization, a great quantity of water is abſorbed into the cryſtals: for a hundred parts of vitriol recently cryſtallized, contained about forty-four parts of water, thirty-ſix of acid, and twenty of iron in ſome meaſure deprived of its phlogiſton; on which account, after evaporation of the water of cryſtallization, they have the property of crumbling away to a whitiſh powder, when expoſed to heat. It is farther remarkable of martial vitriol, that in full and cloſe veſſels it remains unaltered,

but in open veſſels depoſits an ochre, eſpecially when ſituated in a warm place. This phenomenon is owing to the following circumſtance, viz. that iron, diſſolved in vitriolic acid, always contains a certain portion of phlogiſton. When this can eſcape, and paſs over into the air, a proportionable quantity of ferruginous earth is ſeparated in conſequence, which earth can now no longer be held in ſolution by the acid *. When martial vitriol is treated with a briſk fire, it acquires firſt a white, then a yellow, and laſtly a red colour; in which ſtate it is employed for the diſtillation of vitriolic acid. From this reſiduum, which is called *Colcothar*, a ſalt may ſtill be elixated with water, known under the denomination of *Salt of Colcothar*, which concretes in cryſtals of a whitiſh-green colour. This always has iron ſtill for its baſis; but when it is made from the reſiduum of common vitriol, the earths of copper, zinc and alum are at the ſame time found in it for the reaſons mentioned above. The brown-red earth, which remains at laſt, when all the ſaline particles have been extracted from it by boiling hot water, is called ſimply *Brown-red*, or *Sweet earth of vitriol*. For this purpoſe alſo may be uſed that earth, which in the uſual mode of diſtilling aqua fortis is found in the reſiduum.

* The vitriolic acid, to diſſolve iron, muſt be in a proper ſtate of dilution. The reaſon of this is, that this, like all the other metals, muſt part with a certain portion of its phlogiſton, and at the ſame time receive a determinate quantity of air, previous to its ſolution in acids. The nitrous acid indeed eaſily parting with its air, carries off in union with its baſe, and in the form of nitrous gas, the phlogiſton of the metals diſſolved in it. But this is by no means the caſe with the vitriolic acid, which is not ſo eaſily decompoſed. It is therefore abſolutely neceſſary, that a ſufficient quantity of water be preſent, which uniting with the earth of the metal, thydrophloge, the other principle, joins the phlogiſton of the iron, and carries it off in the form of inflammable gas. This theory, founded on the effects of a double decompoſition, and uniting the different and indeed oppoſite theories of *Scheele* and *Lavoiſier*, likewiſe accounts in the moſt eaſy and ſatisfactory manner for the phenomenon, which our Author has here attempted to explain merely on the principles laid down by *Scheele* and *Bergman*: viz. the atmoſpheric air entering into the bottle, combines with the earth of iron, and precipitates it in the form of a calx; at the ſame time that this latter ſubſtance gives out its phlogiſton to the vitriolic acid, the colour of which is by this means darkened.

When much heat is uſed, the concentrated vitriolic acid acts on the iron; becauſe it is at the ſame time decompoſed by it; the air neceſſary for the previous calcination of the metal, being abſorbed by it from the acid, the baſe of which uniting with the phlogiſton, forms either ſulphureous gas, or ſulphur itſelf, according to the degree of heat employed.

During the ſolution, a black powder is precipitated, which M. *Monnet* found to be martial Æthiops. [E.]

*Lead*

*Lead* is merely corroded by the vitriolic acid, when these two substances are combined together directly. But neither is the result observed to be different, when the former is precipitated from its different solutions by the latter. *Tin* requires concentrated acid of vitriol, in order to unite with it. One part of the former must be covered with two of the latter, and evaporated almost to dryness over a gentle fire. As soon as it is cool, a little water is poured over it, and then it is put again in a warm place; when all the tin is dissolved except a slimy residuum, a circumstance which must be attributed to the dissipation of part of its phlogiston.

*Vitriol of copper*, which is produced by the combination of copper with vitriolic acid, is sometimes obtained by the assistance of nature, but sometimes also composed by art. In the former way, the purest, and richest copper ores, without being previously exposed to the air to effloresce, are immediately roasted, then elixated, and boiled down, after which the blue vitriol is obtained from them by crystallization. But as the cupreous pyrites are seldom so good as is requisite forthis purpose, this vitriol is more commonly prepared in an artificial manner, which again is performed in two different ways. The first consists in an imitation of nature; viz. in stratifying sulphur with plates of copper, and treating them with a slow fire in such a manner, that the sulphur may first pervade the copper, and that afterwards by somewhat increasing the fire, they may both be fused together to a kind of slag, which is bruised, boiled up with water, and the decoction evaporated to the point of crystallization. In the other method, two parts of oil of vitriol are mixed with one part of filings of copper, and evaporated to dryness. This saline mass is then boiled in water, evaporated and crystallized. The crystals of this vitriol are compressed dodecaëdrons; the most regular are of the form of a rhomboid, which is truncated in such a manner, that two of its sides are quadrangular, four hexagonal, and six rhombical. A hundred parts of this salt contain twenty-six parts of copper, forty-six of vitriolic acid, and twenty-six of water. It has a deep blue colour, does not crumble to pieces on exposure to the air, though it does when exposed to heat, and has an acrid, coppery, and corrosive taste. In former superstitious times, cupreous vitriol which had crumbled to pieces in a warmer air, was called *powder of sympathy*. The native vitriol may be tried with regard to its purity; viz. whether it be contaminated with iron or zinc, in the following

ways: 1. When an infuſion of it is not made black by a decoction of galls, it contains no iron: 2. A ſolution of it in water, ſaturated with ſpirit of ſal ammoniac, ſhould yield a deep blue tincture, without either a greeniſh or whitiſh powder being precipitated. This ſalt alſo bears the name of *Cyprian vitriol*, or *blue ſtone*.

The *vitriol of ſilver* is obtained by pouring two parts of oil of vitriol upon one part of very fine filings of ſilver, or on ſilver precipitated from its ſolution by copper. This mixture is heated in a glaſs, upon ſand, with a very briſk fire, till it boils, and this is continued till no more bubbles are ſeen to aſcend, and the whole fuſes quietly. This ſalt, the cryſtals of which however are not yet known, is afterwards diſſolved by water. A more eaſy method of making this combination, is to diſſolve the ſilver in nitrous acid, and precipitate it with the vitriolic. *Vitriol of gold* cannot be obtained in a direct manner by acids, though it may by firſt diſſolving the gold in aqua regia, and afterwards precipitating it either with this acid, or with an alkaline ſalt.

From the *nitrous acid* and the different metals, ariſe the *Metallic nitrous ſalts*, of which a few only cryſtallize, and theſe generally deliqueſce again on expoſure to the air. In moſt caſes the nitrous acid is not rendered inactive like the vitriolic; but its corroſive power is not only ſometimes perceptible, but is often increaſed by theſe combinations. This acid acts with particular force upon the phlogiſtic part of metals, and often deſtroys it entirely; upon which depend various phenomena that occur on this occaſion.

A neutral combination of the nitrous acid with the *metal* or *regulus of lapis ponderoſus*, is not as yet known. *Mangane ſe* is united with nitrous acid in the following manner: One part of pulveriſed mangane ſe is put with three parts of nitrous acid into a retort, and the acid diſtilled from it to dryneſs. The reſiduum is then diſſolved in water. To facilitate the ſolution, a piece of ſugar may be added at the beginning of the operation *. The ſolution, like that made with vitriolic acid, is of a pale red colour, but does not yield any concrete ſolid cryſtals.

* As the *pure* nitrous acid contains the ſmalleſt poſſible quantity of phlogiſton, the addition of ſugar, or ſome other matter containing the inflammable principle, is abſolutely neceſſary for the ſolution of a ſubſtance ſo devoid of this principle as mangane ſe. Vid. *Scheele's Obſ. and Exper. on Air and Fire*, p. 85. [E]

tain,

Calcined *cobalt* is diſſolved by nitrous acid with a red colour. By the addition of volatile alkali, the portion of iron merely, which it may happen to contain, is precipitated from it in the form of a grey powder, upon which the ſolution contracts a roſe-pink or purple colour, eſpecially when the alkali is a little redundant. This ſolution when ſaturated, being moderately heated, and uſed as ink for writing, makes the letters red. When the ſolution in mere nitrous acid is evaporated to one half, *nitre of cobalt* is obtained in red cryſtals, which conſiſt of a great number of needles, and form long quadrangular priſms, which however attract the moiſture of the air, and do not detonate upon coals, but part with their acid, and depoſit a dirty violet-coloured metallic calx. *White arſenic* is, it is true, with the aſſiſtance of heat, diſſolved by this acid with the emiſſion of red vapours, yet the cryſtals it forms are, according to *Monnet*, unchanged arſenic. *Nickel* and its calx are likewiſe diſſolved by it, with a green colour, from which, after due evaporation, ſpathiform and deliqueſcent cryſtals are obtained, of a bluiſh-green colour. Pure *antimony* is rather corroded than diſſolved by nitrous acid. *Zinc*, on the contrary, diſſolves eaſily and quickly in it, and at laſt, according to *Monnet*, cryſtallizes to a foliated ſaline lump, which deliqueſces again. *Biſmuth* likewiſe diſſolves eaſily and copiouſly in the ſame acid, and at length concretes in ſlender, pellucid, priſmatic cryſtals, which are called *Nitre of Biſmuth*, but which do not detonate upon coals, and are decompoſed in water. Of all the ſemi-metals, *mercury* is diſſolved by this acid in the greateſt abundance, and with the greateſt eaſe. A ſtrong nitrous acid takes up its own weight of it. The cryſtals, according to *Wallerius*, are polygonous, and almoſt of the figure of a rhomboid, but with more angles; pellucid, and generally of a yellow colour; it is however partly decompoſed again by mere water. This acid does not unite with *platina*.

*Iron* diſſolves very briſkly in the nitrous acid. It is therefore adviſable to uſe, not filings of iron, but ſmall pieces, and by no means a ſtrong acid. At firſt, the acid acquires a greeniſh colour; but after ſaturation it becomes of a brown-red. As ſoon as this is perceived, and that the action of the acid ceaſes, the ſolution muſt directly be decanted off from the iron that lies undiſſolved at the bottom, be the quantity of it ever ſo ſmall, otherwiſe it will grow thick, and like a jelly. No cryſtals can be obtained from it. *Lead* is alſo perfectly diſſolved by this acid, provided only that it has been ſufficiently diluted with

water.

water. The ſolution taſtes ſweet, and, after due evaporation, concretes in white, flattened, triangular cryſtals, with truncated extremities. Theſe cryſtals are called *nitre of lead*. It detonates of itſelf in the fire; but by frequent ſolution and inſpiſſation it yields *oil of lead*. *Tin* is rather corroded than diſſolved by nitrous acid, as long as this latter has any ſtrength. It may nevertheleſs be perfectly diſſolved ſlowly and without heat, by a moderately ſtrong acid, which has been previouſly diluted with eight parts of water. No ſaturated ſolution however is obtained by this means, but even the ſmall portion of tin, that it has diſſolved, will precipitate from it by degrees. *Copper*, on the contrary, is diſſolved very eaſily and without heat by this acid. The ſolution has a ſky-blue colour, and being ſlowly evaporated with a gentle heat, concretes in long, pyramidal, pellucid, blue cryſtals; but if it be abſolutely evaporated to dryneſs, the maſs has merely a cryſtalline, long, radiated appearance, when it is knocked to pieces. This combination is called *Nitre of Copper*.

The proper ſolvent of *ſilver* is nitrous acid, by which it is taken up eaſily and in abundance. During the operation, red vapours ariſe, and the acid grows ſoon green or blue; theſe colours however diſappear entirely towards the end. After the evaporation, or, when the acid that was uſed was of a middling ſtrength, or immediately after the ſolution, white cryſtals are formed in thin laminæ, which are called *Lunar Cryſtals*, or *Nitre of Silver*. In this combination, the corroſive acrimony of the nitrous acid is aſtoniſhingly increaſed, and for this reaſon it is employed as the moſt powerful of all cauſtics; for from it the *Lapis infernalis*, ſo called on account of its effects, is prepared in the following manner. The ſolution of ſilver, being filtered till it is quite clear, is but juſt evaporated to dryneſs; this ſaline maſs is then thrown into a ſmall crucible, which is ſet upon a ſmall charcoal fire for the purpoſe of fuſing its contents. In the beginning, the maſs will riſe a little, but, ſoon after it emits vapours of a deep red colour, ſubſides and fuſes quietly, like a black oil. This is the preciſe point of time when the fuſed maſs ought to be formed into little ſticks *. The ſolution of ſilver tinges all the parts of animals black, and the cryſtals, which are obtained from it, become black

* Mr. *Dollfuſs* (*Pharmaceutiſch-Chemiſche Erfahrungen*) after ſeveral attempts to make this cauſtic with ſilver more or leſs adulterated with copper, found that the copper will ſhew itſelf on the ſurface in the form of a green calx, and attracts the moiſture of the air. The Lunar Cauſtic made with fine ſilver, ſtill farther purified by fuſion with ſedative ſalt, had a whitiſh appearance, and

black in like manner when expoſed to the ſun. Upon this is founded *Schultze's Nocturnal-Magnet* (Scotophorus Schultzii), which is obtained by mixing a quarter of an ounce of pulverized chalk in a glaſs with a drachm of a ſaturated ſolution of ſilver. The whole maſs remains white, but becomes black in the ſun. *Gold* does not enter into any union with nitrous acid.

*Metallic ſalts*, prepared with the *marine acid* do not for the moſt part affect a cryſtalline form, and are much more inclined to deliqueſcence. It is alſo obſerved, that the marine acid does not act ſo powerfully upon the inflammable part of metals as the nitrous acid does.

The *Metal of Lapis ponderoſus*, or *Regulus of Tungſten*, will not combine with the marine acid. The union of *Mangane*ſ*e* with this acid is effected by putting one ounce of it in powder into a retort, with three ounces of ſtrong marine acid, diſtilling the liquor to dryneſs, and elixating the reſiduum with water. Here alſo, as with the two former acids, a ſolution of a very pale red colour is obtained, which does not cryſtallize.

*Regulus of Colbat*, and its calx, both diſſolve in the marine acid with a red colour, the former however very ſparingly, the latter in great abundance. If the ſolution be green, it is a ſign that the Cobalt contains alſo Nickel. In the former caſe, the ſolution yields cryſtals of a red colour inclining to blue, and of the ſhape of a lozenge. Theſe, when diſſolved, afford a ſympathetic ink. *Arſenic* diſſolves indeed in the marine acid; but what cryſtallizes in conſequence of the ſolution being evaporated, is unchanged arſenic. *Nickel* diſſolves, though in a ſmall quantity, in the ſame acid with the aſſiſtance of heat, and forms a deliqueſcent ſalt of a yellowiſh green colour. *Regulus of Antimony*, and ſtill better its Calx, diſſolve in ſtrong marine acid, with the aſſiſtance of heat, but cannot be brought to cryſtalliſe. *Zinc* too combines very eaſily and copiouſly with this acid, of which it takes up above the fourth part of its own weight of it, and that even without the aſſiſtance of heat. During the ſolution, inflammable air makes its eſcape, and no cryſtals appear in conſequence of evapo-

and more that of a ſalt than the common cauſtic of the ſhops has. The proportion of the Nitrous acid thus combined with Silver in its dry ſtate, if ſo it may be called, the proportion, I ſay, of this to the ſilver he diſcovered by accurate experiments to be nearly as twelve to ſeven. In fine, Mr. *D.* recommends the purification of baſe ſilver by converting it into Luna Cornea, and then reducing the Luna Cornea to ſilver. He likewiſe found M. *Wenzel's* method of fuſing it with alkali, preferable to that of *Marggraf.* [E]

ration. The black flakes, which ſeparate during the ſolution, conſiſt probably of ſulphurated iron. *Biſmuth* diſſolves in this acid with great difficulty, and in ſmall quantity, and therefore a ſaturated ſolution cannot be obtained from it. The ſmall and oblong deliqueſcent cryſtals, which appear after the evaporation of the mixture, prove, that ſolution has taken place. *Mercury*, in its fluid ſtate, is with difficulty united with the marine acid. For this purpoſe the acid muſt always be applied to it in a concentrated ſtate by the intervention of other bodies. Neither does this acid act remarkably upon *Platina*.

*Iron* diſſolves in the marine acid in its metallic as as well as in its calcined ſtate. In the former caſe it yields inflammable air. Both ſolutions, however, differ eſſentially with regard to phlogiſton. The ſolution of iron in its metallic ſtate is greeniſh, and concretes into ſparry cryſtals of a bright green, which are compoſed of tetraëdral hollow funnels; when it is precipitated with fixed alkali, there appears a greeniſh precipitate. The ſolution of calcined iron, on the contrary, is of a yellowiſh brown hue, and is alſo precipitated with a browniſh red colour. When there is a redundancy of acid, the cryſtals are ſhaped like needles. *Lead* is rather corroded and converted into a calx, than diſſolved by the marine acid, conſequently an extremely ſmall quantity of it only can unite with this acid in a direct way; from plumbum corneum diſſolved in water, however, a liquid ſolution of this kind is obtained. This acid unites eaſily with *Tin*; only the ſolution goes on very ſlowly, and almoſt imperceptibly. When it is evaporated, very beautiful, ſhining, needle-like cryſtals are formed, which become ſomewhat moiſt in the air, and bear the name of *Salt of Tin*. According to *Beaumé*, it ſerves, among other uſes, as a corroſive, to give brightneſs to certain colours upon cotton, and to make them more fixed and durable. *Copper* diſſolves in the marine acid with the aſſiſtance of heat, without any conſiderable motion being perceived. The ſolution is of a very deep brown hue; but becomes green, when attenuated with water: after ſome time alſo it concretes in dark green cryſtals, which however attract the moiſture of the air.

*Via humida*, the marine acid unites no more with ſilver than it does with gold. This latter metal however is diſſolved by it, when the acid has been previouſly dephlogiſticated, or when it has been impregnated with a little nitrous vapour, or when the gold has been precipitated from Aqua regia.

But

But what the marine acid cannot effect in its liquid ftate, is frequently accomplifhed by it in its concentrated ftate, or in the *dry way*, by which different combinations are obtained, which would otherwife be impoffible. They are mentioned here in order. Thus, from *Quickfilver*, united with the greateft quantity poffible of the marine acid concentrated in the higheft degree, arifes *corrofive Sublimate* of mercury, which is prepared in the following different ways. 1. Eight ounces, for inftance, of mercury are diffolved in ten or twelve ounces of ftrong nitrous acid, or in as much as is requifite for the purpofe; the folution is then diftilled to drynefs, and the faline mafs mixed with eight ounces of decrepitated common falt, and with the fame quantity of vitriol calcined to whitenefs; the whole is then poured into a glafs matras, capacious enough to be filled with it to two thirds only. Upon this the matras is placed upon fand, and a fire kept under it, which is to be increafed by degrees, till the bottom of the veffel begins to glow with an obfcure red heat, and there is no farther appearance of fublimation. Here three decompofitions and two new combinations take place. The nitrous acid flies off, and leaves the mercury in a very decompofed ftate; the vitriol is deftroyed, fince its acid quits the iron, and, in confequence of its nearer affinity, combines with the alkali of the common falt. Thus is accomplifhed the third feparation, viz. that which takes place in the common falt, and at the fame time the firft new combination is made; directly upon which the fecond union takes place, that of the marine acid with the mercury, now very minutely divided, and as they are both of a volatile nature, they now, propelled by the fire, afcend on high, united together, and attach themfelves in the form of a dry, concrete vapour, to the fuperior empty part of the veffel, where they concrete in white cryftals, croffing each other, and pointed at each end, in the form of a lance, which conftitute the corrofive fublimate above-mentioned. But this falt is prepared to *greater advantage*, according to *Kunkel's* method, by boiling ten ounces of mercury, for inftance, and fix ounces of oil of vitriol under a chimney, in a crucible, over a gentle fire, till the mercury is converted to a white folid mafs. This is afterwards mixed with eight ounces of common falt, and fublimed in a glafs matras. It is not neceffary however to perform this operation, dangerous as it always is, one's-felf, fince this product of the fpagyric art is prepared in feveral countries on the large fcale of a manufactory. According to *Ferber*, it is compofed, in the manufactories in Holland, of four hundred pounds of Vitriol of Goflar, calcined to rednefs, two hundred

pounds of well-dried nitre, two hundred pounds of common ſalt, and two hundred and eighty pounds of quickſilver, to which are added fifty pounds of the reſiduum of the preceding ſublimation (which however I hold to be altogether ſuperfluous), and twenty pounds of the impure corroſive ſublimate of the laſt operation. During the mixture of the ingredients, the maſs is moiſtened with a portion of the acid that diſtilled over in the preceding operation, and the whole put upon the fire for ſublimation. The nitre is abſolutely ſuperfluous in this compoſition. For the chief aim is to diſengage the marine acid, and unite it in the largeſt quantity poſſible by the way of ſublimation to the mercury. Corroſive Sublimate conſequently is a mercurial ſalt ſuperſaturated in the higheſt degree with marine acid, a ſalt which cryſtallizes in the form of long needles, which contains as much acid as can be combined with the mercury; hence it is the moſt efficacious poiſon, the very vapour of which is fatal to our lungs *.

Moreover the marine acid, concentrated in and by means of mercury, in the manner deſcribed above, may, after being prepared for the purpoſe in corroſive ſublimate, be brought to unite with various other metallic bodies.

*Manganeſe*, according to *Scheele*, diſtilled with equal parts of corroſive ſublimate, was not altered. What reſults from the combination of *Cobalt* with corroſive ſublimate is not yet known. But when *Arſenic* and corroſive ſublimate are mixed together in equal portions, and diſtilled in a retort over a gentle fire, the *butter of arſenic* is obtained in an inſpiſſated ſtate. As ſoon as this is all come

* In this operation, as M. *Fourcroy*, Vol. III. pag. 131, obſerves, the vitriolic acid diſengages that of the common ſalt: the latter ſeparates the mercury from the nitrous acid, and at the ſame time receives air from it, ſo that it becomes dephlogiſticated muriatic acid, in which ſtate combining with the mercurial calx, it forms corroſive ſublimate (or *Epimuria* of *Mercury*): the nitrous acid being diſſipated in the form of nitrous gas.—M. *Berthollet*, who made this fine diſcovery, has ſince, certainly without ſufficient foundation, relinquiſhed the theory, which appeared to claſh too much with his favourite ideas of the non-exiſtence of phlogiſton: for it muſt be obſerved, that without the doctrine of phlogiſton it will be extremely difficult, if not abſolutely impoſſible, to account ſatisfactorily for the above mentioned phenomena. It is here, as in moſt other decompoſitions, that a double elective attraction takes place: the mercury giving out its phlogiſton to the nitrous acid, at the ſame time that it decompoſes this acid by attracting its air.

In this ſame dephlogiſticated ſtate it is contained in the butters of antimony, arſenic and biſmuth.

The difference between corroſive ſublimate and white precipitate, is, according to M. *Berthollet*, that in the former it is combined with more air and acid. [E]

over, a receiver with water is put on, and the remainder of the mercury, which is now revivified, is alſo expelled with an increaſed fire. When, inſtead of white arſenic, orpiment is uſed, *Butter of Orpiment* is obtained by a ſimilar treatment. Of the effects of the ſame combination with *nickel*, nothing as yet is known, as far as I have been able to learn. On the other hand, the product obtained by it from antimony is more known, and is in general uſe. I mean the *butter of antimony*, which may be prepared after the following different methods. Crude antimony will anſwer the purpoſe here as well as the regulus. Of the former, four parts are mixed with from eight to twelve of corroſive ſublimate: with this mixture, a glaſs retort, which has a tolerably wide neck, is filled two thirds, when it is diſtilled with a gentle fire. In this operation, there comes over, on the one hand, a clear, thin liquor, but alſo on the other hand, quite a thick butter-like ſubſtance is obtained, which attaches itſelf to the inſide of the neck of the receiver. When this ceaſes to come over, the operation is put a ſtop to, the thick matter taken out of the receiver, put into a glaſs capſule, covered with the remaining liquor, and ſet in a damp place to deliquiate. When the regulus of antimony is uſed for this purpoſe, three parts of it are ſufficient to produce ſimilar effects. In this operation, the marine acid, in virtue of its greater affinity, unites with the metallic part of the antimony, and by this union volatilizes it to ſuch a degree, that they are both carried aloft by the fire together. In the firſt caſe, the mercury remains combined with the ſulphur of the antimony; but, in the ſecond caſe, it remains in its metallic ſtate, but ſtill accompanied with a ſmall portion of the regulus, which the marine acid was not capable of ſubliming totally. Conſequently the butter of antimony, which is come over, is in fact nothing elſe than a compound conſiſting of the reguline part of the antimony and the concentrated marine acid. When it is deliquiated, it is alſo called *Oil of Antimony*, and forms a very corroſive liquor, which however is decompoſed by the addition of water, becauſe by this means the metallic part of the ſolution is precipitated. But it may be diluted ſtill better with marine acid, in which caſe it concretes into cryſtals, a circumſtance which *Leonhardi* has alſo obſerved before with reſpect to the diſtillation of butter of antimony, which for the major part concretes into priſmatic cryſtals. From this theory it follows, that the concentrated marine acid may be united with the reguline part of antimony, and the butter of antimony obtained from it in more ways than this one. So early as in *Baſil Valentine*, we find directions for the pre-

paration of ſuch an oil of antimony, by diſtilling antimony, common ſalt and clay, or inſtead of this latter, pulverized bricks. *Rolfinkius*, *Becher*, *Glauber*, *Le Febure* and *Barkhuſen* teach us how to prepare it from antimony, common ſalt and vitriol, but differ from each other concerning the proportion of theſe ingredients. Likewiſe *Glauber*, *Rolfinkius* and *Le Mort* deſcribe how ſuch an oil may be obtained merely by ſolution in ſtrong marine acid and ſubſequent diſtillation. *Lemeri* and *Barkhuſen* order oil of vitriol to be added to this latter mixture. But as all theſe formulæ are attended with their reſpective inconveniencies, I, with a view to ſave the expence of uſing corroſive ſublimate, as well as at the ſame time to obtain the butter of antimony in a liquid form, have, for theſe many years paſt, prepared it with four pounds of common ſalt, three pounds of oil of vitriol diluted with two pounds of water, and one pound of antimony *. This mode of preparing it is, in fact, the ſame with that which Profeſſor Gmelin preſcribed ſome years ago, and which only differs from mine in the proportion of the ingredients †. In the ſame manner likewiſe is obtained

* M. *Dollfuſs (Pharmaceutiſch-Chemiſche Erfahrungen)* tried ſeveral different methods of preparing this cauſtic ſubſtance: Firſt, he attempted to diſtil it from a mixture of crude antimony, common ſalt, and very dilute vitriolic acid in M. *Gottling's* method; but obtained nothing more than a ſpirit of ſalt in which there floated a quantity of ſulphur, and which had hardly diſſolved a few metallic particles. The following formula he found to be the beſt. Two ounces and a quarter of the grey calx of antimony, eight ounces of common ſalt, and ſix ounces of acid of vitriol diluted with four ounces of water. This yielded ten ounces of the *antimonial cauſtic*. With a view to aſcertain the quantity of metal contained in it, he mixed two ounces of it with four ounces of water, when the mixture formed ſo ſtrong a coagulum, that he was not able to pour off any of the water, even after a lapſe of twenty-four hours. The precipitate carefully dried, weighed fifty grains.

The reſult was much the ſame when he repeated the experiment with the pulverized glaſs of antimony. The precipitate was even more conſiderable, half an ounce of the butter yielding ſixty grains. In the reſiduum he found thirty grains of an earth, which was chiefly calcareous muria. Having repeated this experiment at another time, from half an ounce of the butter he obtained but fifty grains of precipitate. [E]

† With reſpect to the hiſtory of butter of antimony, vide *Chem. Journal*, Vol. III. p. 118 & ſeq. M. *Gottling* complains, that on uſing the crude antimony, the veſſel burſt ſeveral times during the diſtillation, and adviſes the ſubſtitution of the glaſs of antimony to the crude antimony. Now, though this accident of a veſſel burſting never happened to me, as frequently as I have performed this operation, yet I muſt confeſs, that the glaſs of antimony may be employed without any great difference in the expence. [A]

the *butter of Zinc*, upon the ſubject of which there is a paper to be ſeen in the *Chemical Journal*. The moſt advantageous method is, to prepare it of equal quantities of white vitriol and common ſalt by a ſtrong, naked fire, which ought to be continued for ſeveral hours. Purſuant to another method, equal portions of white vitriol and fixed ſal ammoniac may be diſſolved in water, each ſeparately, and then mixed together. Here a precipitate is formed, which ought to be ſeparated by filtration, and waſhed with the liquor, that has paſſed through the filter, till all that is ſoluble is extracted. The liquor is then evaporated to dryneſs, and diſtilled in a ſtone retort. In the ſame manner the *butter of Biſmuth* is obtained by diſtillation, from one part of Biſmuth and two parts of corroſive ſublimate, on the rectification of which a very fine powder is always left in the retort, which in colour reſembles oriental pearls, and is extremely ſoft and ſmooth to the touch.

When, farther, the corroſive ſublimate, which is a mercurial ſalt ſuperſaturated with marine acid, is mixed with more mercury, and combined with it by ſublimation, it becomes a barely ſaturated mercurial ſalt, loſes its acrimony, and produces *ſweet Mercury (Mercurius dulcis)*, in which the mercury is combined with as little marine acid as poſſible, to enable it to paſs from the metallic to the ſaline ſtate. For this purpoſe, four pounds of corroſive ſublimate are to be triturated with three pounds of quickſilver in a marble mortar, till there are no more globules to be ſeen, and the whole is converted into a grey powder. While it is triturating, the mixture is to be moiſtened now and then with a little ſpirit of wine, in order to avoid the poiſonous duſt that ariſes from it. The powder may then be put either into a glaſs matras with a wide neck, or into a glaſs bottle, or elſe into ſeveral ſmall phials, and ſet upon the fire for ſublimation. The veſſels ought to be filled with it up to one third at the moſt; and the ſand, in which they ſtand, ſhould reach but very little above the height of the matter contained in them. The fire is to be kept up till the whole is raiſed from the bottom of the veſſel. This firſt ſublimation muſt be followed by two rectifications, and, each time, the quickſilver that has been raiſed along with it, ſhould be mixed afreſh with the more ſolid ſublimate. But that, which remains after the third and laſt ſublimation, in the form of a grey powder, or in a metallic ſtate, is, together with the reſt of the light ſublimate, which has attached itſelf quite to the upper part of the veſſel, to be ſet apart for a future operation, and only the lower ſolid ſublimate kept, as ſweet mercury. Though this circumſtance of ſome mercury in its metallic

ſtate

ſtate ſtill remaining after the laſt ſublimation, be conſidered as the only certain proof of a well-prepared ſweet mercury, yet *Beaumé* has obſerved, that all ſweet mercury ſtill contains a ſmall portion of corroſive ſublimate. For this reaſon it is adviſeable, after triturating the ſweet mercury to a fine and ſubtile powder, to pour upon it ſeveral times a conſiderable quantity of boiling water: and in order to expedite the extraction, in each pound of water may be previouſly diſſolved one drachm of ſal ammoniac *. *Beaumé* attributes the cauſe of this diſadvantage to the following circumſtance, viz. that, at every repeated ſublimation, a part of the ſweet mercury is again decompoſed, and a ſmall portion of the

* It is well known that M. *Scheele* ſome years ago publiſhed a ſhort, eaſy and cheap method of preparing this ſalt by precipitation, as follows. Take of purified quickſilver and common aquafortis, of each lb.ſs. Digeſt this mixture in a heat gradually increaſing, repeatedly ſhaking the matras till the metal is nearly diſſolved. The mixture muſt boil for the laſt quarter of an hour. Then pour off the clear part boiling hot upon another mixture likewiſe boiling, and conſiſting of four ounces and a half of common ſalt, and eight pounds of diſtilled water; a copious precipitation will enſue, pour off the ſupernatant liquor, and waſh the powder that remains behind, with water, till it is properly edulcorated; in fine, dry it upon blotting paper by a gentle heat.

This operation is explained by the illuſtrious diſcoverer, as follows.—" The ſolution of Quickſilver, made in the method indicated above, contains both Mercurial Calx and live Mercury, very minutely divided: when to this, marine acid, (or for greater cheapneſs) common ſalt is added, the marine acid combining with the Mercurial calx, forms corroſive ſublimate, which immediately attracts as much quickſilver as is ſufficient to ſaturate it. This, being inſoluble in water, falls to the bottom as calomel." The method here given of preparing Calomel viâ humidâ, (though it be in itſelf a very good one, and have been adopted into the Swediſh Pharmacopæia) not having met with the approbation of certain critics (among whom, by his total ſilence on the ſubject, we may probly reckon our Author), and as the objections againſt it ſeem chiefly to proceed from the preparation not being ſublimed, M. *Dollfuſs*, with a view to remedy this defect, and to prevent the miſtakes that might ariſe from the corroſive Sublimate employed being not always in an equally ſaline ſtate, had recourſe to ſeveral other modes of making it by ſublimation, the completeſt of which was the following.

Having diſſolved ten ounces of Quickſilver in twelve ounces and a half of oil of Vitriol, and drawn off part of the acid by diſtillation, he mixed the Mercurial Vitriol with an equal quantity of decrepitated common ſalt, and lb.ſs. of crude mercury. This mixture being ſublimed, yielded ten ounces and a half of the beſt kind of Calomel, which, as a proof of its being in a ſtate of ſaturation, even exhibited ſeveral globules of crude mercury on its ſurface. Repeating this experiment on the large ſcale of a manufactory, he ſtill obtained excellent Calomel: but would wiſh this, as well as every other preparation of it, to be edulcorated in the manner here propoſed by our Author. (Vide *Pharmaceutiſch Chemiſche Erfahrungen*, p. 6. [E]

3 live

live mercury ſeparated, in conſequence of which, chiefly the corroſive part adheres to the upper region of the ſubliming veſſel. But it is more probable, that the ſmall portion of the corroſive ſublimate, that remains behind, does ſo merely for this reaſon, that at laſt, on account of its great diviſion among the ſweet mercury, it is not able to act farther upon the quickſilver that is added to it, by which, conſequently, on account of this diminution of its efficacy, it cannot be perfectly dulcified. Now from hence a judgment may be eaſily formed, whether *De la Brune's Mercurial Panacea*, which is alſo called *Calomel*, poſſeſſes all the advantages uſually attributed to it. This panacea is obtained by ſubliming ſweet mercury three times or more over and above the cuſtomary ſublimations, each time with a ſmall addition of quickſilver. In fine, if the mercury is expected to be of a fine white colour and gloſſy, the ſublimation muſt be carried on with a proportionably briſk fire, elſe, when the fire is kept low, the maſs of quickſilver will be too long expoſed to it, and in conſequence of the action of the matter of fire upon it, acquire a reddiſh colour at the bottom of the veſſel, by which means alſo the ſublimate itſelf is afterwards tinged brown. This may partly ſerve to explain the origin of the red powder, which has been found by different Chemiſts at the bottom of the ſubliming veſſel, when probably the ſublimation had been put an end to too ſoon. To ſome, the *red Lion* * immediately occurred on this occaſion; others took it for iron, that had been mixed with the corroſive ſublimate, and theſe latter are in fact ſometimes in the right. In the former caſe too, it is very conceivable, that *Beaumé* might ſtill perceive ſuch a red powder, even at the fifteenth ſublimation; for I am almoſt ready to believe, that, with a moderate and long-continued fire, the whole maſs would by little and little contract this colour, but neither in ſuch a caſe would it greatly differ greatly from any other calx of mercury. Upon *platina* corroſive ſublimate has no particular effect.

But when *Iron* is combined with it, the *martial ſweet Mercury* of *Hartmann* (Mercurius dulcis martialis Hartmanni) is produced, of which *Cardilucius* ſeems to have given the firſt hint. It is prepared by ſublimation with one part of

* A whimſical idea of the antient Chemiſts, or rather Alchemiſts. It appears to be nothing more than Mercurius Calcinatus, or the calx of mercury united with a large quantity of pure air: the baſe of the acid being diſſipated in the operation, and leaving its air behind in union with the metal. [E].

filings

filings of iron and two of corrosive sublimate. In this operation, the iron attracts the redundant acid, and at the same time revivifies part of the mercury. The rest however sublimes in the form of sweet mercury, and at the same time carries up along with it a portion of the iron, which had been dissolved by the marine acid. Besides this, it may likewise be obtained in the following manner. With about two ounces of quicksilver are triturated four ounces of the substance remaining after the preparation of the martial flowers of sal ammoniac, till a perfect union takes place; upon which the powder is put into a retort, which is set deep in sand, and the sublimation begins. Here it is essentially necessary that the fire, as soon as the vessel can bear it, should be increased till the bottom of the vessel becomes red hot, by which a yellowish, and sometimes a brownish-coloured sublimate is obtained, which is impregnated with particles of iron. I also obtained it in another more certain and convenient manner by mixing the above-mentioned residuum with equal parts of mercury, which had already been dulcified, and by subliming them with a brisk fire. When *lead* is added to corrosive sublimate, the concentrated marine acid remains at the bottom, united with the lead, in the state of *Plumbum corneum*, or *Horn lead*, and the mercury passes over in a revivified state. Combined with *tin*, this substance produces the *smoaking spirit of Libavius* (Spiritus fumans Libavii, vel Fumigatorium perpetuum). To five ounces of pure tin, fused in an iron ladle, are added six drachms of quicksilver; this mixture farther is triturated with twenty ounces of corrosive sublimate, then put into a retort, and distilled with a sand heat. In the beginning of the operation, a colourless liquor comes over; after this appear heavy, white vapours, and the butter of tin attaches itself to the roof of the retort in the form of a white, light, dry powder. The mercury is left behind revivified at the bottom of the retort, together with the remainder of the calx of tin. *Copper*, being treated in the same manner with corrosive sublimate, is intimately penetrated by the marine acid, and at the same time the mercury is driven over in its metallic state. One part of the former and three parts of the latter being submitted to distillation, leave behind them a residuum, which liquefies easily in fire, and in the air, and burns with a green flame in the candle.

Corrosive sublimate mixed with *Silver*, and distilled in a retort, suffers the mercury to go over in its metallic state; but its acid remains united with the silver, and converts it into Luna Cornea. This sublimate does not act upon pure *Gold*.

From

From the three mineral acids, which are moſt in uſe, and which we thus far have examined, by the mixture of them with different metals, may be produced various compound ſalts, and other peculiar reſults, of which the major part however have not been ſufficiently inveſtigated. M. *Wenzel's* experiments to this purpoſe are as follow.

The menſtruum, which conſiſts of the vitriolic and nitrous acids mixed together, has not been tried with *Mangancſe*, nor *Cobalt*. *Regulus of Arſenic* it corroded only. Its action upon *Nickel* too is ſtill unknown. *Regulus of antimony* being put into oil of vitriol, to which nitrous acid was afterwards poured, till it was obſerved to act, and then being ſet in a warm place, was diſſolved in a ſhort time with great noiſe and tumult; part of it however fell to the bottom in the form of a powder. The remaining clear ſolution cannot be mixed with water; as in that caſe the metallic part, that was diſſolved, will be immediately precipitated. *Zinc* and *Biſmuth* are diſſolved, but *mercury* is only corroded, by it. Its action upon *platina* is not known. Iron is *diſſolved*, but *lead* and *tin* only corroded by it. Again, it diſſolves *Copper*. It is alſo ſaid, properly diluted, to diſſolve even *Silver*. Its effect upon *Gold* has not been tried.

The menſtruum, made by merely mixing together the vitriolic and marine acids, is ſaid to diſſolve *mangancſe* and *cobalt*. It does not act upon the *regulus of arſenic*; with *nickel*, no experiment has yet been made. *Regulus of antimony* is completely diſſolved by it in its metallic form, and the ſolution may, to a certain point, be diluted with water; but when more water is added to it, the regulus of antimony falls to the bottom, in the form of a grey powder, which however is again diſſolved by oil of vitriol. *Zinc* likewiſe is diſſolved by it. It is remarkable, that *biſmuth*, upon which, neither of the two acids act ſingly, is ſpeedily diſſolved by them, when they are mixed together. When, for inſtance, ſome biſmuth is put into any quantity ad libitum of oil of vitriol, and ſpirit of ſalt is dropped into it, till it begins to act upon the metal, and the glaſs is ſet upon hot ſand, a perfect ſolution is obtained, which has this remarkable property, that it cannot be precipitated by water. *Mercury* and *platina* are not diſſolved by this acid mixture. It diſſolves *iron*, but by no means *lead*. *Tin*, when attended with the ſame circumſtances, which we mentioned in regard to biſmuth, is diſſolved by it, and *copper* ſtill with greater eaſe; but it does not act upon *ſilver* and *gold*.

The third mixture, viz. that of nitrous and marine acid, conſtitutes aqua regia, which diſſolves *mangancſe* and *cobalt*. Of this and the latter metal, the

*ſympathetic ink*, which becomes green, when heated, and was diſcovered by *Hellot*, in the year 1737, is prepared in the following manner: A quantity ad libitum of good zaffre is diſſolved in nitrous acid. It ought however to be previouſly weighed, and care muſt be taken that the acid be ſaturated with it. The ſolution is then filtered, the reſiduum edulcorated with diſtilled water, dried and weighed, that it may be known what quantity has been diſſolved of it. As much as the ſolution wants of its former weight, ſo much common ſalt is added to it, and all the liquor is diſtilled to dryneſs, in a retort. Hereby an aqua regia comes over, and in the reſiduum remains a *nitrum cubicum cobaltinum*, which is to be diſſolved in three times its quantity of diſtilled water. This ſolution has the property, that, when it is written with upon white paper, which after being dried, is expoſed to a gentle heat, the writing or drawing, which before was inviſible, will now appear of a green colour, and diſappear again when it grows cold; but conſtantly reappears every time it is heated. *Scheele* has alſo obſerved, that the green colour is produced whenever the writing is held over oil of vitriol, or quicklime. M. *Ilſemann* has deſcribed a *blue* ſympathetic ink, in the Chemical Annals for 1785, Vol. II. p. 25.* In the ſame manner are diſſolved *regulus of arſenic*, *nickel*, *regulus of antimony*, *zinc* and *biſmuth*. A ſmall portion of mercury is alſo diſſolved by this menſtruum; of *platina* it takes up a ſixteenth part only, with the aſſiſtance of heat; the ſolution is of a deep yellow colour, and when cool, yields ſmall, opake, yellow cryſtals, of an acrid taſte, which fuſing imperfectly in the fire, loſe their acid, and leave a dark-grey calx behind. From platina diſſolved in aqua regia, a fine red *ſalt of platina* is obtained. *Iron* is eaſily diſſolved by this acid menſtruum: for the ſolution of lead the acid ought to be much diluted, and cannot eaſily be ſaturated. *Tin* is diſſolved in the cold, by an aqua regia conſiſting of two parts of nitrous and one of marine acid; but care muſt be taken withal, that neither

* The formula is as follows: Take of an earthy ore of cobalt, as free from iron as poſſible, one ounce: bruiſe it; but not to too fine a powder. Then put it into a cylindrical glaſs, with 16 oz. of diſtilled vinegar, and ſet the mixture in hot ſand, for the ſpace of ſix days, ſtirring it frequently; or elſe boil it directly, till there remain but 4 oz. Filter and evaporate it to one half. If the ſolution be of a roſe colour; you may be aſſured that your cobalt is of the right ſort. A red-brown colour is a ſign of the ſolution containing iron, in which caſe the proceſs fails.—To two ounces of the ſolution thus reduced, add two drachms of common ſalt. Set the whole in a warm place to diſſolve, and then the ink is made.—Another method is given by the ſame, p. 130. [E]

of

of the two acids be too ſtrong, that the tin be put into the menſtruum by degrees, and that after the ſaturation, no redundant tin remain lying in it. If theſe points are neglected, the ſolution will after a certain time acquire a gelatinous quality. *Copper* is very well diſſolved by this menſtruum, but produces no cryſtals. It does not act upon *ſilver*; but for *gold*, the proper menſtruum is compoſed of nitrous acid and ſal ammoniac; in which caſe this ſolution is alſo capable of concreting into yellowiſh-red cryſtals. To the ſame purport is the *ſolutio ſolis ſine ſtrepitu*, for making which, gold is boiled in water with comman ſalt, nitre, and alum.

Beſides theſe, the *fluor acid*, in that ſtate in which it comes over by diſtillation from glaſs veſſels, exhibited, according *Scheele*, the following affinity to metals. Of a combination of *fluor acid* with *mangane ſe*, hardly any thing could be perceived. But *Scheele* has very truly obſerved, that when diſſolved to a ſolution of manganeſe in one of the more common mineral acids, fluor ammoniac diſſoved in water was added, a *magneſium fluoratum** of difficult ſolution was obtained. *Regulus of cobalt* was not diſſolved, but its calx was; the ſolution was of a yellow colour, and became gelatinous. According to *Bérgman*, it unites with *arſenic*, and forms cryſtalline grains. It diſſolves the calx of *nickel* with difficulty, but yet produces with it cryſtals of a bright-green colour, which are called *Nicolum Fluoratum* †. *Regulus of antimony* was as little attacked by it as crude antimony; but it acted violently upon *zinc*, and yielded inflammable vapors. *Biſmuth* in its metallic ſtate, though it be not ſoluble in this acid, yet was diſſolved by it, when calcined. *Mercury* in its metallic ſtate, remained undiſſolved. The calx precipitated from the ſolution by alkali, was in part diſſolved, but alſo in part fell to the bottom again. The precipitate ſubmitted to the blow-pipe, fuſed to a yellowiſh glaſs, the major part of which evaporated by degrees, and left nothing behind, but a fixed glaſs-bead. Of the effect of this acid upon *platina* nothing is known. *Iron* was diſſolved after a ſharp conflict, and inflammable air expelled in the operation; the ſolution taſted like martial vitriol, but was not cryſtallizable, and at length became hard. The fluor acid was expelled by the vitriolic acid, which was alſo accompliſhed by mere heat, a red-ochre

* This ſalt ſhould rather be called, *Fluoricratium Magneſiacum*; in Engliſh, *Magneſian Fluoricrate.*

† This ſalt ſhould rather be termed, *Fluoricratium Niccolinum.*

 being

being at the ſame time left behind; which on being rediſſolved, taſted like alum. Of *lead*, the calx only yielded a ſolution that was ſweet, and was precipitated with vitriolic and marine acid, and likewiſe with ſal ammoniac. The concentrated ſolution ſpontaneouſly yielded a precipitate, from which the fluor acid was expelled by the acid of vitriol; it fuſed eaſily when ſubmitted to the blow-pipe, the acid evaporated, and the lime was reduced; but alſo part of the glaſs was left behind in a fixed ſtate. Tin was diſſolved very eaſily, but in a calcined ſtate only; the ſolution had a nauſeous taſte, and became gelatinous. Copper in its metallic ſtate was diſſolved but little; its calx however was diſſolved much eaſier. The ſolution likewiſe contracted a gelatinous appearance; but nevertheleſs concreted in cryſtals, ſome of which were cubic, and ſome long and of a blue colour. Silver remained unaltered, but its precipitate, prepared with fixed alkali, was in part diſſolved; but part of it precipitated again, and combined with the acid. By the acid of vitriol, the fluor acid was expelled. *Gold* was in no way attacked by it. In all the abovementioned experiments, a digeſtion of ſix hours, and coction for a ſhort time, towards the end, were employed.

Of the effect of *ſedative ſalt* upon *mangane ſe*, and the compound thence ariſing, nothing is known. All ſuch weak acids as this, act in general but very little upon this metallic ſubſtance; whoſe union with them may however be beſt facilitated by employing for this purpoſe the white precipitate, which is produced from the ſtronger mineral acids by fixed alkali, and is of much eaſier ſolution. Though ſedative ſalt does not directly attack *cobalt* viâ humidâ, yet when this metal has been previouſly diſſolved in aqua regia, and borax is added to it, a portion of metallic earth is precipitated; part of it remains however in the liquor united with the ſedative ſalt, which for the ſake of affording conviction to any one that doubts the fact, may be produced from it by alkali. Sedative ſalt diſſolves *white arſenic* both in the moiſt and dry way; and the combination, obtained in the manner laſt mentioned, of equal parts of both, was ſoluble again in water, and by evaporation, a white-greyiſh, and yellow ſaline powder, as alſo ſometimes little ramified aciculæ were obtained from it. Upon *nickel* ſedative ſalt has the ſame effect as upon cobalt, that is to ſay, a combination enſues by means of a double affinity. The ſame phenomena are exhibited by *regulus of antimony*. The *zinc* in vitriol of zinc, is in fact precipitated white by a ſolution

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of borax, at the firſt commencement of the mixture, but is diſſolved again after a very ſhort time. *Biſmuth* was precipitated from its ſolution in the mixed menſtruum of vitriolic and marine acids by borax, in the form of a very white powder, which, after being edulcorated and dried, did not change its colour in the open air, but fuſed to a white tranſparent glaſs in the fire. *Mercury* in its metallic ſtate is not attacked by ſedative ſalt; but when it has been previouſly diſſolved in nitrous acid, it is precipitated of a yellow colour by borax, and the precipitate conſiſts of mercury and ſedative ſalt. This compound, according to *Wenzel*, may be ſublimed in cloſe veſſels, forming a ſublimate of an orange colour. That this precipitate is ſtill a ſaline combination, is ſhewn by its ſolubility in a great quantity of water, from which lime-water occaſions a browniſh red precipitate. No combination of *platina* with this ſalt can with certainty be affirmed to take place, in conſequence of a ſimilar treatment.

Of all metals, *iron* is diſſolved the eaſieſt in ſedative ſalt. After being boiled a quarter of an hour with clean filings of iron, the liquor contracted an amber colour, and on evaporation, yielded a light kind of ſalt in faſciculi, proceeding from the circumference to its center. The part which was next to the ſides of the veſſel, and which probably was firſt cryſtallized, was of a yellowiſh hue. From a ſolution of iron in the vitriolic acid, this ſalt, according to *Wenzel*, was precipitated nearly of an aſh-colour, but the precipitate being edulcorated, fuſed in the fire to a dirt-coloured ſlag. *Lead* is in like manner precipitated from its ſolution in this acid, by borax, and at the ſame time united with the ſedative ſalt. *Tin* likewiſe is thrown down quite white from its ſolution in marine acid, and the edulcorated precipitate fuſed to a grey opaque ſlag. *Copper* was precipitated by borax from its ſolution in vitriolic acid, in the form of a green powder, which after it was edulcorated, did not change its colour in the air. In the fire this precipitate fuſed eaſily to a glaſs-like maſs, which after it had been expoſed to heat for ſome time longer, acquired a fine dark-brown colour. *Silver* was precipitated by borax from its ſolution in nitrous acid, in the form of a yellow powder; which powder being placed upon a gentle fire, in a covered veſſel, acquired the form of an opaque glaſs, of a dark yellow colour; but being laid upon charcoal, was reduced to ſilver by the blow-pipe. *Gold*, according to *Wenzel*, at firſt was not to be precipitated from aqua regia, by borax, but at laſt ſuddenly exhibited a precipitate, that reſembled fulminating gold; only it was a little darker, and made a much weaker exploſion than

ordinary;

ordinary; consequently the sedative salt united with the gold had actually diminished the fulminating property of the gold.

The *arsenical acid*, as it is called, or dephlogisticated arsenic, unites with *manganese* when this substance is dissolved in acetous acid, and at the same time precipitate with the former acid. It dissolves *cobalt* in a small quantity, and on being digested, acquires a rose colour. But when the cobalt was dissolved in an acid, it could by no means be precipitated by that of arsenic, which however was done by the arsenical neutral salt. According to *Bergman*, the acid of arsenic composes with the *calx of nickel* a green and concrete saline mass. According to *Scheele*, nickel imparted a green colour to it, by the assistance of heat, on which occasion, a great quantity of grey powder, mixed with arsenic, was separated. Nickel could not be precipitated from other acids by the abovementioned, but was precipitated by means of the neutral salts of arsenic. *Regulus of antimony* was a little attacked by a solution of dephlogisticated arsenic, and precipitated again by the addition of water. *Butter of antimony* could not be decomposed by it, but was by the arsenical neutral salts. In digestion with *zinc*, this acid occasioned an effervescence; and the solution was rendered turbid by a copious black powder. The air that was generated on this occasion, neither united with water, nor rendered lime-water turbid, nor was absorbed by two thirds of common air; and on being set fire to by a candle, regulus of arsenic was separated from it. (A striking instance of the great dissolving power of the air, which shews, that these kinds of air are not compounded till the instant of their escape from the body, and that they acquire peculiar properties, according to their different constituent parts.) In the dry way, inflammation with explosion took place. The solution of zinc in vinegar only could be precipitated by dephlogisticated arsenic; but all the rest were precipitated by the arsenical neutral salts.—*Bismuth* was corroded by the acid of arsenic; but the solution was precipitated by water, and the precipitate consisted of bismuth and the abovementioned acid. In the dry way, it was calcined by this acid, but not dissolved. In *Scheele's* experiments, *mercury* was not acted upon by this acid. From the vitriolic and nitrous acids, it was precipitated by this acid, in a yellow, but from the corrosive sublimate by the neutral salt of arsenic only, of a white colour. Mixed with sweet sublimate of mercury, it yielded corrosive sublimate.—*Platina* was in no wise acted upon by the abovementioned acid. *Iron* was dissolved by means of digestion, by a decoction of arsenic, and gave a high yellow colour to the filtered liquor, which also

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concreted in cryſtals of a peculiar form; theſe conſiſted of ſmall dark brown hemiſpheres, of which ſome floated on the ſurface of the liquor, exhibiting their flat ſide, ſome lay at the bottom and exhibited their convex ſide; in the greateſt part of them alſo a central point was plainly to be perceived. *Lead* was likewiſe but little acted upon by this acid, by being digeſted with it, but more ſo when the latter was abſtracted from it by diſtillation, in a retort. But, on the other hand, ſolutions of *lead* in the nitrous, marine and acetous acids were precipitated by this acid; and from theſe precipitates, on the addition of ſome pulverized charcoal, the arſenic was ſublimed, and the lead reduced. *Tin* digeſted with a ſolution of the arſenical acid, firſt grew black, then was ſurrounded with a white powder, and finally, the whole mixture became gelatinous. This metal was likewiſe precipitated by it from vinegar, but not from the mineral acids; but from all of them, by the neutral ſalt of arſenic; and from the precipitates of difficult ſolution, by the addition of powdered charcoal, regulus of arſenic was ſublimed.—*Copper* is diſſolved by the acid of arſenic viâ humidâ, as well as precipitated by it from its ſolution in acetous acid. Arſenic alſo, when mixed with copper, and boiled with water, diſſolves this metal in a ſmall quantity. After evaporation, a ſalt of a greeniſh colour, inclining to yellow, and without any particular form, remains behind. It is remarkable of this ſolution, that it is not tinged blue by volatile alkali, like any other ſolution of copper combined with arſenic, and that therefore the copper cannot be diſcovered in it. Otherwiſe this combination may likewiſe be made by mixing a ſolution of copper in vitriolic or nitrous acid with a ſolution of the neutral ſalt of arſenic. A ſolution of acid of arſenic could not even diſſolve the ſmalleſt quantity of *ſilver* by being digeſted with it; but the liquid part being drawn off from it in a retort, the mixture, on the fire being increaſed, formed a glaſs, which was diſſolved by the acid of arſenic, and left a brown powder behind it, from which ſolution, the marine acid threw down a luna cornea. The ſolution of ſilver in nitrous acid is alſo precipitated by the neutral ſalt of arſenic, on which occaſion, the arſenic unites with the ſilver, and forms with it a precipitate of a dark brown colour, inclining to red. *Gold* could not be brought to a ſimilar combination either by a decoction of arſenic, or the acid, or the neutral ſalt of arſenic.

Of the combinations of the *molybdenic* acid with metals, as yet very little is known. We only know that they exert ſome little action upon metals. By being boiled with the filings of all the baſe metals, it grows at laſt bluiſh.

 Mercury,

Mercury, lead and ſilver, are thrown down by it from their reſpective ſolutions in the nitrous acid. Theſe precipitates are reduced upon a piece of charcoal, in which operation the fuſed earth enters into the coal. Juſt as little we know even at this preſent time, of the effect which the acid of *Tungſten*, or *Barylithic acid*, has upon metals. It precipitates *zinc*, *iron* and *copper*, from their ſolutions in the vitriolic acid; likewiſe lead, mercury and ſilver, from their ſolutions in the nitrous acid; as alſo lead from its ſolution in the marine acid, all of a white colour; but tin from the marine acid, blue. If this acid be mixed with ſome drops of marine acid, and ſpread over poliſhed iron, tin or zinc, it acquires a fine blue colour.

In the *phoſphoric acid*, the precipitate only of *Manganeſe* is ſoluble. The ſolution looks red, but becomes white on being expoſed to the air, and re-aſſumes its red colour again, when filtered upon calx of manganeſe, but loſes it again upon a freſh expoſure to the air. The *calx of Cobalt*, boiled with phoſphoric acid, produced a dark wine-coloured ſolution. With the *calx of Nickel*, the acid yields a greeniſh ſolution. It acts but little on the *regulus of antimony*; but the calx of Antimony precipitated by an alkali, is more copiouſly, though but ſlowly diſſolved, from which ſolution the alkalies and zinc precipitate an aſh-coloured powder that is eaſily vitrified. By evaporation, a dark-green ſubſtance is obtained, which feels greaſy, effervеſces and throws up a ſcum when expoſed to the fire, and at length is vitrified. *Zinc* is briſkly diſſolved with an offenſive ſmell. *Biſmuth* is alſo affected by this acid; but the calx of Biſmuth, precipitated with alkali, is more copiouſly diſſolved, inſomuch that from the clear ſolution are produced cryſtals, which retain their form and ſolidity in the air, and are ſoluble again in water. *Mercury*, in its metallic ſtate, is not acted upon by the phoſphoric acid; but the red calx of mercury loſes its red colour by it, becomes white, and, by a briſk digeſtion, black. Mercury diſſolved in nitrous acid, is precipitated white by it; but after a certain time is all diſſolved again, except a ſmall portion of black, heavy powder. It attacks *platina* juſt as little; but when it was treated with it in a retort, and the liquor had been drawn off from it by diſtillation, the reſiduum detonated with a flaſh of light and a loud report. *Iron* it diſſolves briſkly and entirely, and forms cryſtals with it; it alſo precipitates this metal white from its ſolutions while it unites with it. *Lead* and *Tin* are in ſome meaſure attacked by this acid, if it be not too much diluted. It is tinged green by *Copper*, but it acts on the calx of Copper ſpeedily and with

greater

greater vehemence. It does not unite in a direct manner with *Silver*; but when the latter has been previoufly diffolved in nitrous acid, this acid mixes with it, at firft limpid and clear, but afterwards the mixture grows turbid, and but a very little falls to the bottom. All this being evaporated to drynefs, yields a refiduum, which has the appearance of Luna Cornea, and fufed by the blow-pipe on a piece of charcoal, forms a glafs of a dark grey colour. Upon *gold*, this acid feems not to act at all; the metal being feparated by it from its folution in Aqua Regia after fome time in its original metallic fplendour.

Of the operation of the *acid of Amber* upon metals, and of the metallic falts refulting from this operation, the following is all that is known. Experiments with *Manganefe*, *Cobalt*, *Arfenic* and *Nickel* are wanting.—Its action upon *Regulus of Antimony*, as well in its metallic ftate as in that of a precipitate, was hardly perceptible.—According to *Stockar de Neuforn*, *Zinc* was eafily diffolved in it. According to *Wenzel*, a folution of the precipitate of zinc in acid of amber, after evaporation, yielded cryftals, which were compofed of long and flender laminæ lying one upon the other.—Agreeably to the report of the former of thefe authors, *Bifmuth*, though with rather greater difficulty, was yet diffolved by this acid with the affiftance of heat. But the latter, on the contrary, having previoufly diffolved it in another acid and precipitated with an alkali, diffolved it in the acid of amber and obtained yellow cryftals, which were compofed of fmall, fhort and flender laminæ, lying by the fide of each other.---*Mercury* in its metallic ftate is not acted upon by this acid; but the precipitate of it obtained by alkali is, in the evaporated faline mafs of which no cryftals of a determinate figure were to be feen.—It did not act upon *platina*.—*Iron* was pretty foon diffolved in this acid, but without any perceptible effervefcence. The folution had a yellowifh colour, and after fome time threw down a large quantity of brown ochre. According to *Wenzel*, a folution of iron precipitated from another acid by an alkali, yielded cryftals, which were compofed of fmall, brown, pellucid laminæ, almoft in the form of a ftar.—A *precipitate* of *lead*, prepared with alkali, was alfo diffolved in this acid, and yielded cryftals in form very much refembling thofe which were obtained from zinc with the fame acid.—According to *Stockar de Neuforn*, *tin* was diffolved by this acid, with the affiftance of heat; the whole of it however fell to the bottom again, in the form of a white calx. In *Wenzel's* experiments, a folution of tin precipitated by an alkali, formed in the fame acid thin pellucid cryftals, with broad laminæ.—According to the former of thefe writers, *copper* was diffolved by a long continued digeftion, by which digeftion the folution ac-

quired a grafs-green colour. But according to the latter, the folution of a precipitate of copper, prepared with alkali, yielded cryftals of a pale green hue, which in their figure very much refembled cryftallized calcareous fpar.—*Silver*, which had been precipitated by an alkali from its ufual menftruum, was, according to *Wenzel*, likewife diffolved by this acid, and concreted into cryftals, that confifted of long thin laminæ, lying one upon the other. All thefe fuccinated metallic falts continued dry in the air, but were decompofed in the fire, on which occafion the falt of amber efcapes, and leaves the metallic bodies behind. No experiments made with *gold* are extant.

The *acid of lemons* diffolves the *precipitate* of *manganefe*, and likewife yields a brownifh-red uncryftallizable folution with the *calx of cobalt*.—It alfo diffolves a fmall quantity of *white arfenic* and in like manner of the *precipitate* of *nickel*, and *calx* of *antimony*, but more copioufly the *calx* of *zinc*.—According to *Wenzel*, it did not act upon *bifmuth*.—With *mercury* precipitated by fixed alkali, the acid of lemons produces a limpid folution, from which however no cryftals arife.—No combination of *platina* with this acid is known.—A brown folution is obtained with it from *iron*.---The *calces* of *lead* are likewife pretty copioufly diffolved in it; but it acts much lefs upon *tin*. --With *copper* and its calces, it produces green folutions, which however are uncryftallizable.---According to *Marggraf*, this acid likewife exhibits its diffolving power upon the *precipitate* of *filver* made with an alkali; and yields by digeftion, a limpid folution; but by coction, a blackifh turbid one.---Of its effects upon *gold* nothing is known.

The effects of the *acetous acid* upon metallic bodies, and the phenomena which occur on thefe occafions, differ greatly according to the ftrength of this acid. In moft cafes it muft neceffarily be employed in its greateft ftrength, if a faline combination is expected from it. Vinegar affects *manganefe* but little; but the ftrongeft fpirit of vinegar acts with more vigour, efpecially upon the *precipitate* of this metal. According to *Wenzel*, half an ounce of the moft concentrated diftilled wine-vinegar, diffolved 108 grains of earth of *cobalt*, in which operation 38 grains of air made their efcape; the folution had a brown-red colour, and on being evaporated, yielded a falt, which when expofed to heat is blue, after cooling however becomes red, and attracts the moifture of the air.---Of the effects of vinegar upon *arfenic*, thus much only is known, that the latter may be diffolved by it. Befides this, Meffrs. *de Morveau*, *Maret* and *Durande*, in their *Elements of Theoretical and Practical Chemiftry*, Vol. III. p. 30 & feq. mention the

following obfervation, viz. that a mixture of equal parts of foliated earth of tartar and arfenic, diftilled in a retort, yielded firft a liquor as limpid as water, which had a ftrong fmell of garlick: after this a liquor of a brownifh-red colour was collected in another receiver, which filled the receiver with a thick cloud, and had an intolerable fmell of arfenic. By the following property, this feems to be a *liquid phofphorus*; for, when it had been poured upon a filter, and hardly a few drops had paffed, a very thick ftinking fmoak fuddenly rofe as high as the ceiling of the room; an ebullition enfued towards the edge of the filtering paper, and a fine rofe-coloured flame broke out, that lafted for fome moments.---From *nickel* diffolved in the acetous acid, *Bergman* obtained a fpathiform-green cryftalline falt. *Nickel* in its calcined ftate is alfo diffolved by boiling vinegar.---Of *regulus of antimony*, as well as of its different calces, and the glafs prepared of them, in every cafe a very fmall quantity only is diffolved; and from this proceed all the effects of the different emetic wines of *Ruland* and *Huxham*. Zinc is diffolved by concentrated fpirit of vinegar, both in its metallic and calcined ftate; and after due evaporation of the liquor, forms folid, tranfparent cryftals, compofed of thin laminæ, which refemble Glacies Mariæ, and remain dry in the air. ---Concentrated fpirit of vinegar diffolves but a fmall portion of *bifmuth*, but more of it in its metallic ftate than when calcined. The folution does not yield any cryftals.

*Mercury* in its metallic ftate is not acted upon by this fame concentrated fpirit of vinegar; with far greater force does this acid act upon its red calx; and in like manner on a precipitate prepared with fixed alkali from the folution of mercury in nitrous acid. From the folution of this latter fubftance, Dr. *Weftendorf* obtained a great quantity of cryftals, which in their external form refembled fedative falt, and, after being dried, were very light. In other refpects they were found to be of a filver colour, of eafy folution, and greafy to the touch. In half an ounce of concentrated vinegar, M. *Wenzel* diffolved feventy-four grains of the above mentioned mercurial precipitate. This acid does not unite with *Platina*.

*Iron*, in its metallic form, is diffolved by ftrong acetous acid, yet does not yield any cryftals, but the folution acquires in the air a dark-coloured pellicle, which by degrees fubfides to the bottom, till at laft all the iron, that had been diffolved, is in this manner feparated again. Thefe thin laminæ are diffolved again in water, and tinge it quite of a dark red colour. *Lead* in all the ftates, into

 which

which it can ever be brought, may be united with the acetous acid. Lead ſcraped or beaten to thin plates is ſlowly diſſolved both by weak and ſtrong acetous acid. When this ſolution is gently evaporated, long priſmatic cryſtals are obtained from it; but by a contrary proceſs it forms only ſmall needle-ſhaped cryſtals, which have a ſweet taſte like ſugar, and are therefore called *Sugar of Lead*. This article is made in great manufactories in Holland and England, and ſold at ſuch a rate, that it is to be bought cheaper than one could poſſibly make it one's-ſelf. At Rotterdam there are divers manufactories, where this ſalt is chiefly prepared from flake-white*, which the manufacturers buy from the white-lead manufactories. This, reduced to a very fine powder, is boiled in deep leaden caldrons with diſtilled vinegar, till the latter is ſaturated; the ſolution is then filtered, again evaporated in leaden veſſels, and expoſed to the open air to cryſtallize. Inſtead of flake-white, pure ceruſs would anſwer the ſame purpoſe; but on account of its being uſually adulterated by the manufacturers with chalk, or other earths of a white colour, the former is preferred, as it cannot be ſo eaſily adulterated. The remaining calces of lead, though they are all as ſoluble in vinegar as this, yet do not yield any cryſtals, the cauſe of which ſeems to be the matter of fire, ſtill contained in them. Theſe latter calces are for this reaſon uſed for making *vinegar of lead*, from which *Goulard's extract of Saturn* differs in this, that for making the latter, the vinegar of lead muſt be evaporated till it begins to let the lead it has diſſolved fall down again in thin, ſlender laminæ. It is conſequently nothing elſe than a concentrated vinegar of lead. *Tin* is but very ſparingly diſſolved by vinegar, and according to *Wenzel* and *Weſtendorf*, does not afford a cryſtalline ſalt; though *Ferber* mentions, that he had been ſhewn a ſalt of tin in a manufactory at Rotterdam, which had concreted into uncommonly large cryſtals, almoſt in the form of ſalt-petre, and was ſaid to be prepared with vinegar. *Bergman* alſo ſays, that the ſolution may be brought to cryſtallize. *Copper* in its metallic ſtate is but ſparingly diſſolved by acetous acid; but when it has been previouſly corroded by this acid, ſo as to form a green calx, or precipitated by a fixed alkali from any of its ſolutions in the mineral acids, it is much eaſier diſſolved by it, and in this caſe, after evaporation, alſo forms cryſtals of a ſea-green colour, which are known by the very improper name of *diſtilled Verdigreaſe* (flores æru-

* In the original *Schieferweiſs*, i. e. ſlate-white.

ginis,

ginis, viridis aeris); the proper name for it is *Cryſtallized Verdigreaſe* (Aerugo cryſtallizata *).—*Silver* in its metallic ſtate is not in the leaſt acted upon by the acetous acid, while, on the contrary, the precipitate of ſilver, which is obtained by means of fixed alkali from a ſolution of this metal in nitrous acid, may be copiouſly diſſolved in a ſtrong acetous acid, from which alſo beautiful, glittering cryſtals are obtained in the form of needles. The very ſame kind of cryſtals appear alſo when a ſolution of ſilver is added drop by drop to a ſolution of Terra foliata Tartari. In the ſame manner too was *Gold*, in *Weſtendorf's* experiments, after it had been precipitated in the form of fulminating gold, diſſolved by the ſtrongeſt ſpirit of vinegar. The ſolvent power exhibited by the acetous acid upon thoſe metallic precipitates, which are obtained by an alkali from ſuch metals as it does not act upon elſe, depends on a certain portion of acid, which incontrovertibly ſtill adheres to ſuch precipitates, and cannot be ſeparated from them by any kind of edulcoration whatever.

All the poſſible combinations of the *vinegar* of *wood* with metals have not as yet been tried. From the few, however, which are known, it appears, that for the moſt part they agree in effect with thoſe above deſcribed of the common acetous acid.

From the union of the *acid of ſugar* † with the different metals, according to *Bergman's* experiments, the following combinations ariſe. It attacks *Cobalt* either with or without heat, and converts it into a powder of a dilute roſe-colour. The ſolution has more of a yellow appearance, and exhibits cryſtals likewiſe of the ſame colour, which on account of their ſuperabundant acid are eaſily ſoluble; but the roſe-coloured powder, which does not change, is ſcarcely

* M. *Dollfuſs*, in order to produce the *Cryſtalli Veneris*, or verdigreaſe, inſtead of purifying the common verdigreaſe by diſſolving it in vinegar and cryſtallizing it again, tried the method propoſed by M. *Wenzel*, purſuant to which he made a ſolution of fifteen ounces and two drachms of ſugar of lead, and at the ſame time another of twelve ounces of blue vitriol. The two ſolutions being mixed together, the lead was immediately precipitated in combination with the vitriolic acid, and the acetous acid united with the copper was ſupernatant. The liquid being ſeparated by filtration from the vitriol of lead, and evaporated for cryſtallization, he obtained from it five ounces of cryſtallized verdigreaſe. The vitriol of lead, though he waſhed it ſeveral times with water, never loſt its green colour. It may either be uſed in this ſtate as a green pigment, or it may be made perfectly white by digeſting it with diluted nitrous acid. Vide *Pharmaceutiſch Chemiſche-Erfahrungen*. [E]

† Or rather the *oxaline* acid. [E]

ſoluble

ſoluble in water. The acid of ſugar in a moderate heat takes up more than an equal weight of precipitated cobalt; on the addition of common ſalt, this ſolution yields a ſympathetic ink. The ſaccharine acid ſeparates cobalt from all the acids yet known.---*Manganeſe* effervefces with acid of ſugar even without heat; the ſolution depoſits a powder, which, with the addition of ſome more acid, is ſoluble again in water. The name of this compound is *Saccharated Manganeſe* * (Magneſium Saccharatum). *Arſenic* in its reguline ſtate is ſcarcely diſſolved by the aſſiſtance of heat, but white arſenic is eaſily taken up even without heat; on evaporation it exhibits priſmatic cryſtals, which melting with a gentle heat, emit the redundant acid, and concrete in elegant ramifications; theſe eaſily diſſolve in water and in ſpirit of wine, tinge the tincture of turnſole red, are ſublimed by a gentle fire, but deſtroyed by a ſtronger; the ſaccharine acid firſt flying off, and at laſt the arſenic with a ſmell like garlick.---The *regulus* of *Nickel* in digeſtion with this ſame acid is covered with a greeniſh-white cruſt, and at length falls gradually to a powder of the ſame colour. The green calx undergoes the ſame alteration of colour, even without heat. This combination contains twice as much acid as metal. The ſaccharine acid throws down a powder of the ſame kind from nickel diſſolved in the vitriolic, nitrous and marine acids. This ſalt is diſſolved in water in ſmall quantity, and aſſumes a yellow colour, very ſlightly tinged with green; the cryſtals are of the ſame colour. *Regulus of Antimony* grows black in digeſtion with this acid, but the calx and the glaſs are diſſolved, though but little. The ſolution conſequently contains always a redundant acid, and depoſits cryſtalline grains, which are with difficulty ſoluble in water. A ſimilar combination takes place when acetated or vitriolated antimony is precipitated with ſaccharine acid; but it does not enſue with butter of antimony. With *Zinc* the ſaccharine acid effervefces violently, and occaſions it to be ſpeedily covered with a white powder. This ſaline powder in one hundred parts contains ſeventy-five parts of metal, and is not ſoluble in water, unleſs the acid is added in a larger quantity. The ſame powder likewiſe is obtained by pouring the ſaccharine acid upon the calx of zinc, or by precipitating zinc from its ſolutions in the vitriolic, nitrous or marine acids, by this acid.---*Biſmuth* likewiſe has merely its colour darkened by this acid, but the calx is diſſolved. This ſalt is alſo powdery and white, and ſcarcely ſoluble in water; the metal conſtitutes one half of its weight. If to a ſolution of biſmuth in nitrous acid, the ſaccharine acid be added

* More properly *Magneſian Saccharocrate.*

drop by drop, in the ſpace of an hour polygonal tranſparent grains concrete at the bottom of the veſſel, which have the ſame properties as the above-mentioned powder, and are not made ſo opaque by the water as are the cryſtals of nitrated biſmuth.

*Mercury* is not acted upon by acid of ſugar; but when it has been promiſcuouſly calcined, the combination takes place in the form of a powdery, white ſalt, which is not ſoluble in water, unleſs the acid predominates. It grows black when expoſed to the ſun. The ſame combination alſo enſues, when a ſolution of mercury in the vitriolic or nitrous acid is precipitated by acid of ſugar. Corroſive ſublimate diſſolved in water is precipitated but ſlowly and in ſmall quantity by it, and the powder does not grow black in the light. *Platina* is not not diſſolved by ſaccharine acid, unleſs it be firſt diſſolved in aqua regia, and precipitated by fixed alkali. But as the common vegetable alkali unites in ſome meaſure with diſſolved platina, and precipitates it in the form of a powder of difficult ſolution, to which without a doubt ſome of the aqua regia, or at leaſt of the marine acid adheres; *Bergman*, to avoid confuſion, made uſe of the mineral alkali to precipitate platina. This precipitate being edulcorated, yielded a yellow ſolution and yellow cryſtals, when combined with the acid of ſugar.

The acid of ſugar attacks *Iron* with effervescence. The ſolution taſtes ſweet and aſtringent, and exhibits priſmatic cryſtals of a greeniſh yellow colour, eaſily ſoluble in water, and yet falling to powder in heat. In one hundred parts there are fifty-five of acid, and forty-five of iron. The acid being expelled by fire, there remains a ferruginous maſs, marked with ſhining, tranſparent ſquammulæ on the ſurface; but the nucleus verges to a brown colour. Calx of iron is alſo diſſolved by this acid, but in digeſtion yields a yellow ochre only, ſuch as is precipitated in ſimilar circumſtances from green vitriol, and is alſo acquired in the preparation of the ſaccharine acid, when the nitrous acid for this purpoſe employed contains iron. This powder is almoſt inſoluble in water, but on boiling ſeparates an ochre. *Lead* is only darkened in its colour by acid of ſugar; but ſcarcely otherwiſe diſſolved unleſs it be calcined, or, which is ſtill better, precipitated with an alkali from its ſolutions in acids. This ſaturated ſolution depoſits cryſtalline grains; the ſame happens upon adding acid of ſugar to a ſolution of lead in the nitrous, marine, or acetous acid. Theſe cryſtals in one hundred parts contain fifty-five of lead. They do not diſſolve in ſpirit of wine, nor even in water, unleſs a quantity of ſaccharine acid be added to it. Lead diſſolved

in

in the vitriolic acid is not precipitated by the acid of ſugar. *Tin* is firſt blackened by the acid of ſugar by the aſſiſtance of heat, and at length covered with a grey powder. The ſolution emits elaſtic vapours, has an auſtere taſte, and exhibits priſmatic cryſtals; but when quickly evaporated to dryneſs, it acquires a corneous appearance; and on being diſſolved afreſh, on the addition of alkali it yields a copious precipitate. The calx of tin is alſo eaſily diſſolved, and both theſe combinations make the tincture of turnſole red---Acid of ſugar attacks *Copper*, even in its metallic ſtate, but with greater eaſe, when it has been previouſly diſſolved by another acid, and precipitated by an alkali. Both ſolutions form a powder of a dilute blue colour, which, unleſs ſome more acid of ſugar be added, is ſcarcely ſoluble in water. Twenty-one parts of copper require twenty-nine of acid. The very ſame ſalino-metallic combination takes place, when a ſolution of copper in the vitriolic, nitrous, or marine acid is precipitated with ſaccharine acid. The Colour of a ſolution of this ſalt, is a mixture of blue and green, from which the copper is precipitated by zinc and iron. The acid of ſugar decompoſes acetated copper ſo completely that the acid of vinegar may be ſeparately collected, only a little adulterated with copper.

Acid of ſugar diſſolves *Silver* only when precipitated by an alkali from the nitrous acid, but elſe ſparingly. This combination is moſt conveniently obtained from a ſaturated ſolution of ſilver in nitrous acid: the ſilver, on the addition of the acid of ſugar, precipitates in the form of a white powder, which, when waſhed, does not change the tincture of turnſole, ſcarcely diſſolves in water, much leſs in ſpirit of wine, but yet is ſoluble in nitrous acid. Expoſed to the rays of the ſun, it grows black. Acid of ſugar deſtroys the union of the vitriolic acid with ſilver, but not that of ſilver with marine acid. Acid of ſugar does not act upon *Gold*, even when aſſiſted by heat; yet if it be precipitated by a fixed alkali from its menſtruum, and waſhed with boiling water, it grows black, but is ſcarce perceptibly diſſolved.

The combinations of the pure *acid of tartar* with the different metallic bodies have been found to poſſeſs the following properties. The liquid tartareous acid, aſſiſted by heat, acts violently and with effervescence upon *Manganeſe*, and produces a brown ſolution. The *Precipitate of Cobalt* is diſſolved with a red colour in concentrated liquid acid of tartar. The ſame menſtruum likewiſe diſſolved *white arſenic*, but a ſmaller quantity of *Calx of Nickel*. Calcined

*Antimony*

*Antimony* unites with this acid, when boiled with it. But with *Bismuth* the combination must be made by adding acid of tartar to the nitrous solution of this semi-metal, upon which, in the space of from ten to fifteen minutes, pellucid crystalline grains are produced, which exhibit a *Tartarized Bismuth* (Bismuthum tartarizatum).---This acid attacked *Zinc* very violently, yet did not dissolve it; but, according to *Paecken**, corroded it to a white calx. The same acid in a concrete state, mixed with half its weight of *Mercury*, formed a grey powder, which may be called *tartarised Æthiops*.---The precipitate of mercury made by an alkali from nitrous acid, as also mercury calcined by itself, likewise the common red calx of mercury, were all attacked by a solution of tartareous acid, but soon fell to the bottom again in the form of heavy, yellow precipitates. Corrosive sublimate was not altered by it. But a solution of mercury in nitrous acid deposited a heavy white powder, which, on being converted into vapour, changed the colour of a silver spoon, in the same manner as is done by the *pulvis Constantini*.—There is no experiment known to have been made upon *platina*.

*Iron* was dissolved by this acid with a slight effervescence, but was deposited again in the form of a grey powder, or rather grains. In a gentle heat, the solution of this acid was tinged with a reddish purple colour, by a crocus martis precipitated from vitriol of iron by alkali; but on evaporation it resembled a resinous, liver-coloured mass.---Acid of tartar unites very easily with the *calces of lead*, and precipitates lead from its solutions in nitrous acid and vinegar.---*Tin* dissolved in the marine acid was not made turbid by this acid, and, on being evaporated, crystallized likewise without rendering the solution turbid. —This menstruum did not act upon *Copper* in its metallic state; nor precipitate its solutions in the nitrous and marine acids. After a certain time, however, it deposited some small crystals of a green colour, but of no regular form. The solution was of a lively green, and exhibited after evaporation, a greenish shapeless mass.—This acid could not be combined in any way with *Silver* or *Gold*.

The effects of the *Acid of Benzoe* upon metals, and the various properties of these combinations are likewise among the facts that are as yet unknown.'

* *Mathias a Paecken*, Diss. de Sale acido essent. Tartari Goettingen, 1779. [A]

† Rather *Tartar of Bismuth*. (*Tartarus Bismuthicus*, Lat.) [E]

On the effects of the *animal acid of fat* upon metals, various obſervations have been publiſhed by Profeſſor *Crell*. *Mangancſe* is copiouſly diſſolved by this acid, and the ſolution continues clear and limpid. *Regulus of cobalt* was not, but the precipitate of it was, diſſolved by this acid. *White arſenic* united but very ſparingly with it. It did not act upon *regulus of nickel*, but diſſolved the precipitate of it from nitrous acid with a green colour. *Regulus of antimony*, with this acid, aſſiſted by heat, exhibited a ſolution, which in the cold grew milky, though, when warm, it had been clear and tranſparent. After evaporation it had a cryſtalline appearance, and did not attract any moiſture from the air. *Zinc* was very eaſily diſſolved by this acid, imparting to the ſolution a peculiar metallic taſte, and by fixed alkali was precipitated from it again in the form of a whitiſh powder. *Biſmuth* in its metallic ſtate was not diſſolved; the precipitate of it was. It did not act upon *mercury* in the cold, though it did, after having been twice diſtilled from it, and poured upon it afreſh. The ſolution obtained from it ſilvered copper-plates, that were put into it, but did not give a precipitate with common ſalt; on the contrary, the liquor, after having been mixed with this ſalt in abundance, ſtill ſilvered a clean copper-plate. It acted ſtill ſtronger upon a precipitate from corroſive ſublimate, from the ſolution of which, after the liquor had been drawn off by diſtillation, a white ſublimate was obtained, which was precipitated white by ſalt of tartar.---This acid acted likewiſe upon *platina*, after it had been diſtilled from this metal to dryneſs, and poured again back upon it, in conſequence of which the ſolution acquired a golden colour, and with fixed alkali afforded a precipitate of the very ſame colour as that given by this metal, which diſſolved in the ordinary menſtruum. This precipitate was alſo ſoluble in aqua regia, to which it imparted a golden colour.---In particular platina, that was precipitated by ſpirit of wine from aqua regia, was diſſolved by it in great abundance. *Iron* was very eaſily diſſolved in it, and exhibited a liquor of an aſtringent taſte, that concreted in needle-like cryſtals, which did not deliqueſce in the air.---*Lead* was diſſolved in it with greater difficulty, and indeed was rather corroded by it, and rendered the acid turbid. Minium is diſſolved in it with greater eaſe; but is previouſly deprived of all its colour, and converted into a white powder before it can be diſſolved. The ſolution has a ſweetiſh taſte, and is not precipitated by common ſalt. *Tin* was corroded ſo as to form a yellow calx, and was diſſolved but very little.---*Copper* was attacked by this acid without heat, and tinged it green; heat however very

very much promoted the ſolution. When evaporated, it ſhewed a diſpoſition to cryſtallize, but again attracted moiſture from the air.---On the the other hand, it attacked *ſilver-leaf* very little; though ſome ſilver was precipitated by means of copper, and alſo the marine acid rendered the ſolution ſomewhat turbid. The calx of this metal, precipitated from aqua fortis, was more copiouſly diſſolved by it. Beſides this, the animal ammoniac, prepared from this acid, as alſo the pure acid itſelf, precipitated ſilver white, from its ſolution in nitrous acid.—Its action upon *gold* alſo was very inconſiderable, for half an ounce of this acid having been diſtilled four times almoſt to dryneſs from ſome gold-leaves, and at length poured back upon them again, the precipitate of a dilute ſolution of tin obtained by it, acquired only a faint colour rather inclining to red. But a mixture of two parts of this acid with one of nitrous acid, diſſolved gold very rapidly.

Finally, the affinity of the *acid of ants* to metallic bodies, remains to be mentioned, as far as they are known from the experiments made by M. *Marggraf* and M. *Arvidſon.* Precipitate of *manganeſe* diſſolves without difficulty in this acid, and then yields coloured ſpathous cryſtals, whoſe oppoſite angles were cut off parallel to each other, and diſſolved in fifteen times their quantity of water. Of *cobalt*, *arſenic* and *nickel*, the calces only were attacked by this acid: among theſe, the ſolutions of cobalt and nickel concreted chiefly in irregular cryſtals. Even with the aſſiſtance of heat, this acid acted very little upon *regulus of antimony* and its calces; which for this reaſon likewiſe ſuffered no conſiderable change from fixed alkali.---*Zinc* it diſſolved very copiouſly with the aſſiſtance of heat; and after filtration, depoſited very beautiful ſolid cryſtals, which were of a kind quite different from thoſe which zinc uſually exhibits with diſtilled wine-vinegar. The calx of zinc alſo was diſſolved, though very quietly.---With *Biſmuth* it exhibited the ſame properties as with regulus of antimony. It does not diſſolve *Mercury* calcined per ſe; on the contrary, the mercury is rather revivified during digeſtion. Its affinity to *platina* is unknown.---It acts violently upon filings of *iron* in a ſtrong heat, and concretes in ſmall cryſtals, a circumſtance which does not take place with diſtilled vinegar.---Filings of *lead* are not acted upon by it even when aſſiſted by heat. But minium is ſoluble in this acid by means of a briſk digeſtion, and after evaporation, concretes in very fine cryſtals, pretty much reſembling the ordinary ſugar of lead. Filings of *tin* were ſcarcely perceptibly attacked by it.---*Copper* was alſo of extreme difficult ſolution in it, but calcined copper was acted upon when ſubjected with it to a briſk digeſtion. The ſolution exhibited very fine

solid cryſtals, of a green colour.---*Silver* was only ſoluble in it when precipitated by fixed alkali from its ſolution in nitrous acid, and well waſhed; and even then it required a boiling heat. Silver was precipitated from it by the marine acid, fixed alkali and copper: but cannot be precipitated by this acid from its ſolution in nitrous acid. No particular effect of it upon *gold* is known.

The combinations of all the known acids with the different metals having now been mentioned, thoſe experiments yet remain to be adduced, according to which metals may be united to alkaline ſalts, from whence ariſe various kinds of *alkaline metallic ſalts*, being produced ſome in the dry, and others in the humid way.

*Mangeneſe* fuſed with fixed alkali, yields a dark-green maſs, which diſſolves alſo with the ſame colour in water, but from this changes to red. It does not greatly differ from the mineral chameleon, which will be deſcribed in another place. I know of no experiment relative to the ſolution of *cobalt*, by fuſion with *fixed alkali*; but it may be very well united with a liquid ſolution of this ſalt. The arſenical neutral ſalts beforementioned, evidently prove the combination of arſenic, as well viâ ſiccâ, as humidâ, with this ſalt.---No combination with *nickel* in the former way is known; and very little of it is diſſolved in the other. *Regulus of antimony* and *zinc* are united with it, in very ſmall quantities, by fuſion with alkali; but when precipitated from their ſolutions by phlogiſticated alkali, the precipitate is again ſoluble by an additional quantity of that lixivium. According to M. *de Laſſone*, *zinc* is alſo ſoluble with effervefcence, in a ſolution of fixed cauſtic alkali. In the very ſame manner may *Biſmuth* alſo, when precipitated, be rediſſolved.---*Mercury*, according to *Wallerius*, may be united with an alkali in the following manner: any quantity ad libitum of purified alkali is fuſed in a crucible; in the mean time half this quantity of mercury is heated in an iron ladle, to ſuch a degree, that it begins to boil; this is poured into the crucible on the fuſed alkali, which then effervefces; upon this the mixture is ſuffered to ſtand ſtill for a little while, after which it is ſhaken about and poured into an iron mortar. By this means the mercury is rendered ſoluble in water. It is not corroſive, and might perhaps be employed in medicine. According to *Weſtendorf*, the ſolution is ſtill more copious when made in this method with cauſtic alkali. Beſides this, according to *Marggraf*, mercury precipitated with lixivium of blood from its ſolution in nitrous acid, may be rediſſolved, if the

lixivium

lixivium be then added in ſuch quantity as to be redundant.---*Platina* cannot by any means be brought to combine with fixed alkali.

*Iron*, by fuſion with alkali is made fit to be afterwards partially diſſolved in water by this ſalt. In the moiſt way this metal is leſs acted upon by alkali. But the way in which it may be united in the greateſt abundance with this ſalt, is as follows: A ſaturated ſolution of it is previouſly made in nitrous acid, and ſmall portions of this ſolution are gradually poured into a ſtrong ſolution of alkaline ſalt, till the alkaline fluid acquires a blood-red colour. In pouring in the latter of theſe ſolutions, the iron, it is true, is ſeparated from the nitrous acid; but, on the veſſel containing it being ſhaken a little, it is in an inſtant perfectly rediſſolved by the alkali. This is *Stahl's alkaline tincture of iron*.---*Lead* and *tin* are in both ways but very little affected by this ſalt; but when either of theſe are kept, with a fourth part of nitre, about a quarter of an hour in a red-hot crucible, an alkaline ſolution may be obtained with water.---*Copper* is only corroded by it ſo as to form a green calx; but if a cauſtic ley be evaporated two or three times from it to dryneſs, a fine blue ſolution will be obtained at laſt; which is ſtill eaſier effected with a precipitate of copper.---*Silver* and *gold* are diſſolved by lixivium of blood, under the ſame circumſtances as mercury.

By means of *volatile alkali*, the following metallic combinations may be made. Its effect upon *mangane∫e* is not known.---Calcined *cobalt* diſſolves in ſpirit of ſal ammoniac, with a cherry-red colour.---The combination of *arſenic* with volatile alkali has already been mentioned.---This ſalt diſſolves calx of *nickel* with a blue colour. Calx of *antimony*, precipitated by volatile alkali from the ſolution of this metal, is rediſſolved by the addition of more ſpirit of ſal ammoniac; and by a ſolution of hepar ſulphuris precipitated from this menſtruum in the form of a browniſh-red powder.---*Zinc* is united to volatile alkali under the ſame circumſtances; indeed, it is even diſſolved ſlowly by it in its metallic ſtate.---In the ſame manner alſo *Biſmuth*, after being precipitated from the acids, by means of volatile alkali, was rediſſolved on the addition of more alkali.--- *Mercury* precipitated from any of the acids by fixed alkali, was likewiſe, according to *Wenzel*, diſſolved both by the cauſtic and mild ſpirit of ſal ammoniac.---I do not know that this ſalt has any ſimilar effect upon *platina*.

When *iron* occurs in the form of Berlin blue, and ſpirit of ſal ammoniac is poured upon it, this latter extracts all the blue colour from it, and aſſumes a

yellow

yellow colour. This liquor is a real ſolution of iron in a volatile lixivium of blood, and may by any acid be precipitated from it blue.---It has not yet been found practicable to unite *lead* and *tin* with volatile alkali in like manner.— *Copper* is diſſolved in all circumſtances by volatile alkali, in which operations various phenomena occur. Volatile alkali, whether diſſolved in water or ſpirit of wine, or made cauſtic by lime, always acquires a fine dark blue colour, from copper. When dilute ſpirit of ſal ammoniac is ſaturated with filings of copper, it forms quadrilateral ſpathiform cryſtals, with bilateral apices, the flat ſides of which unite at the pointed angles like the roof of a houſe. Theſe cryſtals are of a dark blue colour. But they fall to pieces on expoſure to the air, part with the volatile alkali, and become green. Spirit of ſal ammoniac prepared with ſpirit of wine, and impregnated with copper, in an inſtant loſes the copper it held in ſolution, together with all its blue colour, and becomes colourleſs again, on an equal portion of a ſaturated ſolution of fixed alkaline ſalt in water being poured to it. The latter, on the contrary, takes up the copper from the former, and is tinged blue by it; while the former floats on its ſurface quite colourleſs, and may be ſeparated quite unaltered. It is true, the cauſtic ſpirit of ſal ammoniac is tinged of the ſame dark blue colour, but it loſes this colour again on being excluded from the air, on occaſion of which, in addition to theſe M. *Scheele* obſerved the following circumſtances. When filings of copper are poured into a bottle, and the bottle is quite filled with cauſtic ſpirit of ſal ammoniac, ſo that there is no empty ſpace left, and it is immediately ſtopt up, no ſolution takes place. But when the bottle is left open, only for a ſhort time, or there is a ſpace in it left empty, a colourleſs ſolution is obtained, which in the air acquires a blue colour; but which may be deprived of this colour again as often as the operator pleaſes, by letting it ſtand, cloſe ſtopt up, upon freſh filings of copper. From the whole of this we conclude, that the copper in this caſe is not diſſolved till it has loſt a little of its phlogiſton, to which the air, by the attraction it exerts upon it, contributes its ſhare. If this have taken place only in a ſmall portion, and the farther acceſſion of air be prevented; the remainder

* The air ſeems to act here, as in the caſe of the metals diſſolved by acids, by partially calcining the metal, with which it unites at the ſame time that it expels part of the phlogiſton. But this latter not being abſolutely ſeparated, ſtill continues to be in ſome meaſure in union with the calx and volatile alkali, which is the cauſe of the colour as well as the weak connection of the parts in the blue ſolution. [E]

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is diſſolved without any colour, which however appears in the inſtant, that by a freſh acceſſion of air, the phlogiſton ſtill remaining finds means to eſcape. The diſſolved earth of copper is always precipitated, when the ſolution meets with a phlogiſticated copper; and hence the ſolution may be deprived of its colour, in a cloſe veſſel, as often as the operator pleaſes. The colourleſs ſolution is precipitated by zinc and vitriolic acid, but not by iron; it taſtes rather ſweet, and does not ſmell very ſtrong of volatile alkali; while, on the contrary, the blue ſolution has a pungent ſmell, and is precipitated by diſtilled water.

*Silver* precipitated from nitrous acid by volatile alkali, according to *Marggraf*, is rediſſolved by the addition of more volatile alkali, and after the redundant volatile ſalt has evaporated in the open air, concretes into cryſtals, which after exſiccation by heat, are copiouſly diſſolved in ſpirit of wine. From this ſolution, the ſilver was precipitated by the marine acid and common ſalt; alſo by pure acid of urine; but not by the fuſible ſalt of urine; nor by vitriolic acid.---Under the ſame circumſtances *gold* was alſo diſſolved in the form of a precipitate, by the addition of a redundant volatile alkali; it did not cryſtallize however, but rather precipitated again from its menſtruum, on expoſure to the open air.

In all the abovementioned ſolutions of metallic precipitates by alkaline ſalts, for the explication of the effect, recourſe muſt undoubtedly be had to the acid of the menſtruum, which is ſtill contained in the precipitates *.

Beſides the ſimple ſalino-metallic combinations hitherto mentioned, finally a few other *more compounded metallic neutral ſalts* remain to be deſcribed. Probably precipitate of *manganeſe* might be united with tartar by boiling.---In this manner Dr. *Sieffert* obtained a *cobaltic tartar*, in conſequence of having boiled half an ounce of cobalt three times, each time with the ſame weight of cryſtals of tartar; the firſt of which decoctions was of a browniſh, the ſecond of a greeniſh-blue, and the third of an actual blue colour. The fourth decoction, though no freſh tartar had been added, was red, and yielded by cryſtallization a beautiful ſalt, of the colour of peach bloſſoms. The powder of cobalt that remained behind, was of the ſame hue, and probably might have yielded more of ſuch ſalt, if ſome freſh tartar had been added to it.---*Arſenical tartar* is obtained by boiling white arſenic with equal parts of cryſtals of tartar, by which proceſs the

* Rather to the air left in the metallic earths by the ſeparated acid; as alſo to their conſequent dephlogiſtication. [E]

whole of the arſenic is diſſolved. When this lixivium is dried in the ſun, a ſmall-grained ſhining ſalt of difficult ſolution remains behind.—*Antimonial tartar* conſiſts of tartar loaded with particles of antimony, for which purpoſe either the liver, or crocus, or the calx prepared merely by calcination, or glaſs of antimony, or finally, powder of algaroth may be employed. The beſt critique on this prepartion is to be met with in *Bergman's* Treatiſe on Antimonial Tartar. Liver of antimony is the unfitteſt for this purpoſe; the crocus is the moſt uſed, but the glaſs of antimony is the beſt. In order to obtain this precipitate always of an equal degree of efficacy, the abovementioned author recommends it to us to boil gently five ounces of pulverized cryſtals of tartar, with two ounces and two drachms of powder of algaroth in ſeveral pounds of water, for the ſpace of half an hour, then to ſtrain off the ſolution, to evaporate it in a veſſel of ſtone-ware, till a pellicle appears, and finally to keep it in a gentle heat till cryſtals form in it, which are to be taken out and dried. Theſe cryſtals are reſplendent, and have the ſame weight as the tartar uſed in the operation. The purer ſaline cruſts which adhere to the ſides, weigh about half an ounce, and muſt be waſhed well with cold water, and kept ſeparate. The thick lixivium that remains behind and is of a browniſh-red colour, is thrown away. Though this mode of preparing emetic tartar be perfectly free from fault with regard to medical purpoſes, yet conſidered in another light, it is too expenſive, and for this reaſon will not in all probability be generally adopted. The whole of the defect in the uſual mode of preparing tartar emetic, lies in this: viz. that the boiling of the cryſtals of tartar with the different preparations of antimony, is not continued long enough. My practice is to boil one pound of finely pulverized glaſs of antimony with two pounds of pulverized cryſtals of tartar for ten hours in an earthen veſſel, with a ſufficient quantity of water; (taking care however, at proper intervals, to filter off the ſaturated decoction, and pour freſh water upon the reſiduum) and then to filter the lixivium, and evaporate it to dryneſs. To make this medicine in ſmall quantities, one pound of water may be put to each ounce of cryſtals of tartar. With theſe precautions I always obtain an emetic tartar, which in the quantity of from three to four grains, produces every deſirable effect. Beſides this there is a *terra foliata antimonialis tartari*, which is made by ſaturating a lixivium of antimony with diſtilled vinegar, and diſtilling it to dryneſs. *Antimonial vitriolated tartar*, (tartarus vitriolatus antimonialis) is obtained from the firſt cryſtals of the lixivium procured in the waſhing of diaphoretic antimony. The ſubſequent cryſtallizations of the ſame lixivium yield long ſpicular

cryſtals,

cryſtals, which are cool to the taſte, detonate upon coals, and are called *Antimonial nitre*, (nitrum antimoniatum). Both theſe latter ſalts ſtill contain a diſſolved calx of antimony, which after they are diſſolved in water, may be precipitated from them by vitriolic acid, and is in fact nothing more than diaphoretic antimony. Hence too it is that antimonial nitre merely fuſes to a thick magma upon the fire. Its other peculiar property, in conſequence of which its acid is expelled by every other weaker acid, as marine acid, vinegar and acid of lemons, &c. proceeds from part of its nitrous acid being phlogiſticated in the detonation, and being in this ſtate but looſely united with the antimonial baſe; conſequently this acid has the ſame property as a phlogiſticated vitriolic acid, which likewiſe may be diſengaged by another weaker acid.---*Tartar of Zinc* is generated by boiling ſufficiently a calx of zinc precipitated with an alkali, or elſe flowers of zinc, with twice its quantity of cryſtals of tartar, and evaporating the lixivium. By the combination of *mercury* with tartar, a *mercurial tartar* is alſo compoſed. This may be done in different ways. *Monnet* thought he had beſt attained this end, by boiling an ounce of a brown calx of mercury, which had been precipitated from a ſolution of mercury by fixed alkali, with three ounces of cryſtallized tartar and a ſufficient quantity of water, upon which the evaporated lixivium, by means of cryſtallization, yielded a mercurial tartar*. The celebrated *pulvis Conſtantini*, which has been imagined to poſſeſs the power of converting the baſer metals into gold, is, in fact, nothing elſe than the combination reſulting from the mercury of corroſive ſublimate and from tartar that has been made ſoluble by borax.

By a ſimilar combination a *martial tartar* alſo is obtained, by boiling with one part of pure filings of iron, four parts of pulverized cryſtals of tartar, till by the iron all the tartar is made ſoluble, after which the lixivium may be ſuffered to cryſtallize ſlowly, or elſe evaporated to dryneſs. Or, cryſtals of tartar are treated in the ſame manner with a fourth part of their weight of martial vitriol. If the one or the other of theſe mixtures are boiled down to the conſiſtence of honey only, and their ſoluble parts extracted with ſpirit of wine, *Glauber's*, or *Ludovici's Tincture of Iron* is obtained. But it is ſtill better, inſtead of ſpirit of wine, to uſe good French or Rheniſh wine for this preparation, by which means a ſtronger tincture is obtained.---Under this head too come the *martial flowers of ſal ammoniac* (flores ſalis ammoniaci martiales), which are prepared with one pound

* More ways of making this combination are deſcribed in *Monnet's* Treatiſe on the combination of mercury with Tartar. [A]

 of

of purified ſal ammoniac and two ounces of lapis hæmatites by ſublimation. Inſtead of the lapis hæmatites, half an ounce of crocus martis precipitated from vitriol, will anſwer the purpoſe, to which alſo may be added two ounces of ſpirit of ſalt, in order to ſaturate this calx of iron with it, and thus prevent the decompoſition of the ſal ammoniac. Or from one ounceto ten drachms of clean iron filings may be uſed with equal advantage. As this ſublimate has a ſmell of ſaffron, our fanciful forefathers called it *Aroma Philoſophorum*, and *Flores Calendulæ minerales*, likewiſe *Aroph Paracelſi*. From the reſiduum, by extraction with alcohol, is obtained *Mynſicht's tincture of iron*. Even from the martial flowers of ſal ammoniac themſelves a gold-coloured tincture of iron may be extracted by alcohol, which differs but little from *Beſtuſchef's nervous tincture* *.

For

* Vid. *Martin Henry Klaproth's* Hiſtory of Beſtuchef's Nervous Tincture in *Sellen's Neuen Beytragen zur Natur. & Arzneywiſſenſchaft.* Vol. I. Berlin, 1782. 8vo. p. 137—158. [A]

Beſtuchef's nervous Tincture is a ſolution of iron in vitriolic æther or in dulcified ſpirit of vitriol, made by expoſing martial muria with either of theſe fluids for ſome time to the ſun. [D]

The hiſtory of this Noſtrum, which has been in high repute in many parts of Europe for above half a century, and is recommended in many obſtinate chronic complaints, ſuch as weak nerves, gout, hypochondriaſis, &c. is ſhortly this: It was introduced to the world under the name and auſpices of the late Count *Beſtuchef*, Field-marſhal in the Ruſſian ſervice, by whoſe orders both the yellow and the white tincture were prepared and ſold at a very high price. But, not long after this medicine had come into vogue in Pruſſia and other nothern countries, it made its appearance in France likewiſe, under the title of *General de la Motte's Golden Drops*; *(Elixir d'Or, and Elixir blanc de M. le General de la Motte:)* the perſon who had been entruſted by Count *Beſtuchef* with the preparation of it, having violated his oath of ſecrecy and ſold the arcanum at Hamburgh, to the abovementioned French officer, to whom it proved a ſource of great riches; he having had the addreſs to procure from the King of France in 1730, not only a patent and excluſive privilege for the ſale of it, but a handſome penſion; and ſelling it at the rate of a Louiſdor the half ounce phial.

The yellow drops having the remarkable property of entirely loſing their colour in the ſun, and regaining it in the ſhade, rendered the public ſtill more attentive to them, and indeed induced many Chemiſts to ſuppoſe that they conſiſted of a ſolution of gold, an error which was politicly encouraged by *de la Motte* himſelf. M. *Beaumé* even perſuaded himſelf that he had penetrated through the myſtery, and accordingly publiſhed the preparation to the world, which conſiſted of a calx of gold precipitated from aqua regia with fixed alkali, and rediſſolved in nitrous acid, to which was then added a large proportion of ſpirit of wine. But others who were not miſled by appearances, having found nothing but iron in theſe drops, the queſtion concerning their contents remained undecided till the year 1762, when the celebrated *Model* of Peterſburgh, who was now entruſted with the preparation of this medicine, in his Letters publiſhed the

hiſtory

For the proper preparation of this latter, a dark-brown ſublimate is employed, which is ſublimed with an increaſed fire from the martial flowers of ſal ammoniac. It deliqueſces in a moiſt air. Of this liquor, with Alcohol, or Hoffman's liquor anodynus mineralis, the above-mentioned tincture is prepared by mere mixture. When this mixture has been expoſed to the ſun, till it is become quite white, it is put in a dark place, where it acquires a golden colour.---But if inſtead of iron, a calx of copper is ſublimed with ſal ammoniac in the above-mentioned proportion, the ſublimate bears the name of *Ens Veneris*. In both caſes, the ſal ammoniac exhibits its peculiar effect of carrying aloft with it even the metallic particles of bodies. The cauſe of this lies in the marine acid, to which the volatilization of the metals may be properly attributed, whence always a certain portion of ſal ammoniac is deſtroyed, and ſome marine acid adheres to the ſublimed metallic particles. Not very different from the latter is *Stiſſer's arcanum antepilepticum*, for the preparation of which a ſolution of vitriol of copper is mixed with weak ſpirit of ſal ammoniac till all the cupreous precipitate which is ſeen in the beginning of the operation, at length diſſolves, and a mixture is produced, which is quite of a dark-blue colour, in which, after it is ſomewhat evaporated, a dark-blue ſalt cryſtallizes on the addition of ſpirit of wine.---It is

hiſtory of it; and though obliged by his oath to keep the preparation a ſecret, yet he aſſured the public that the baſis of the yellow tincture was not gold, but iron.

At length however about the year 1780, this arcanum was generouſly communicated to the world by the authority of the preſent munificent Empreſs of Ruſſia, who beſtowed upon *Model's* heirs a gratification of 3000 rubles for giving up the ſecret. The recipe is perplexed, tedious and expenſive, but properly condenſed, is nearly as follows: Six pounds of common pyrites and 12 of corroſive ſublimate are to be triturated, and then ſublimed together 6 or 8 times, till all the mercury is expelled. The reſiduum is to be thrice boiled with three times its quantity of water, and as often filtered, and laſtly, diſtilled to dryneſs. By increaſing the fire, at length a martial ſalt will be ſublimed into the neck of the retort. To three drachms of this are then to be added twelve ounces of highly rectified ſpirit of wine, and the whole expoſed to the rays of the ſun. This is the yellow tincture.—The white tincture appears to be of little value, being only prepared from the reſiduum left after the laſt ſublimation, by pouring upon it twelve pounds of highly rectified vinous ſpirit, and drawing this latter gently off by diſtillation, after they have ſtood together a few days.

M. *Klaproth* ſhews, that this tincture has actually abſorbed into its ſubſtance phlogiſton from the rays of the ſun, by the following ſimple experiment. He poured a few drops of a ſolution of ſalt of tartar into two ounces of diſtilled water, and divided this liquor into two parts. Into one glaſs having poured a few drops of the tincture that had not been expoſed to the ſun-beams, the iron was precipitated in the uſual form of a yellow ochre. Proceeding in the ſame manner with the liquor in the ſecond glaſs, that *had* been expoſed to the ſun, the metal was precipitated of a bluiſh-green colour. [F.]

alſo ſaid, that from a precipitate of copper diſſolved in tartar and water by coction, by mere evaporation of the clear lixivium, a tranſparent ſubſtance of a blue colour and of eaſy ſolution is obtained, which exhibits a *cupreous tartar*, and is ſaid to be ſimilar to the *ſuperfine Brunſwick green*.

*Silver* may alſo be brought into the ſtate of one of theſe more compounded neutral ſalts by diſſolving one drachm of it, for inſtance, in nitrous acid, and then adding one or two drachms of purified nitre, and cryſtallizing the whole together (*luna purgans hydragoga*). Likewiſe, by ſuperſaturating a ſolution of ſilver with volatile alkali, and evaporating it to dryneſs. Beſides theſe inſtances there are a great number of other compoſitions poſſible, the major part of which however are fallen into diſuſe.

As the different neutral ſalts have been treated of in the order deſcribed before, it now remains farther for us to take a review of the *phlogiſtic-ſaline compounds*, which ariſe from the union of igneous, and inflammable ſubſtances with various kinds of ſalts.

From the combination of *pure fire* with *acids* ariſe the ſmoking acids, which have been deſcribed before. The condition moſt requiſite for the production of theſe, is that they be previouſly deprived of all their water. Hence this matter vaniſhes again likewiſe, on their being expoſed to the open air, or diluted with water, or united with alkaline ſalts. The reſult of the combination of the whole ſubſtance of *phlogiſton* upon acids has been mentioned occaſionally above, ſo that nothing more occurs to be ſaid of it here.

By the combination of the pure matter of fire with the *alkaline* ſalts, theſe latter ſubſtances are put into a cauſtic and corroſive ſtate. The neceſſary condition, which muſt immediately precede this combination, is the depriving them of the aerial acid, which they contain, in the ſame manner as it muſt alſo neceſſarily take place previouſly to their being made into neutral ſalts. By this alteration of their nature the alkaline ſalts acquire the following properties. They attack all phlogiſtic bodies with greater violence, and conſequently diſſolve them much faſter than before. They have now a much greater attraction to water, and hence are no longer capable of cryſtallization. They no longer efferveſce with acids; but grow hot on being mixed with them, and yield neutral ſalts, which do not cryſtallize ſo well as uſual. They alſo no longer precipitate ſo well as they did before, bodies diſſolved in acids; farther, they do not loſe their fire, on being diluted with water, ſo ſpeedily as acids do.---Fixed alkaline ſalts are made cauſtic as well by being expoſed

exposed to a red heat, as also by means of other bodies, which already by the action of fire have been rendered void of air, and copiously filled with the matter of fire; as by a reciprocal affinity they take the aerial acid from the alkaline salts, and on the other hand yield their matter of fire up to them. But the volatile alkaline salts can only be brought in the latter manner to undergo a similar alteration.

Both the fixed alkaline salts, the *mineral* as well as the *vegetable alkali*, are most conveniently put into the caustic state here described by fresh well-burned lime. But what quantity of the latter ought to be employed on the former cannot be determined by any fixed weight. According to *Meyer*, one pound of purified alkali extracted from pot-ash, requires three pounds and a half of quick-lime. The lime is first slaked with a sufficient quantity of water, and then the alkali, with the portion of water that is still necessary, for this purpose, is added to it. The best method is, after setting this mixture upon the fire, to bring it at once to the boiling point, then to pour it out immediately upon a bleached linen-cloth, and strain off the clear part of the lixivium. The magma that remains upon the strainer may be boiled once more in the kettle with a sufficient quantity of water, and again passed through the strainer. I have frequently however found the quantity of lime here prescribed, too great; since it is not of the same quality at all times, and in all places. We ought therefore to endeavour to ascertain the true proportion by certain appearances, which are easily known, and upon the strength of which the process may be performed every where. For the quantity of purified alkaline salt which I intend to make caustic, my practice is to slake the quick-lime in the proportion mentioned above, with water sufficient to give it the consistence of honey. I then pour the alkali, dissolved in a sufficient quantity of water, into a copper kettle, and immediately add one half of the slaked lime to it, and make it boiling hot; upon which I pour a small portion upon a filter, and try the ley that has passed through the filter, whether any bubbles of air are still to be seen rising in it, on the addition of diluted vitriolic acid: should any appear, I still add some of the remaining lime, and repeat the former proof; proceeding in this manner, till a small portion of the ley, which is filtered till it is as clear as water, ceases to exhibit the least effervescence with diluted vitriolic acid. If rather too much lime has been added already, it is known by this circumstance, viz. that such a ley is soon covered with the usual pellicle, and is made turbid by another solution of alkaline salt. It is true, a small surplus

of

of lime fo added is not very detrimental, yet ftill it is better to endeavour to hit the true point of faturation. This then is a *perfectly cauftic ley*, and upon thefe principles fhould every *foap-ley* be prepared. It is remarkable notwithftanding, that ftill a proportion of calcareous earth is found diffolved in it. The ley obtained in this method is then infpiffated to drynefs, in an iron veffel, over a moderate fire, and the falt, which on increafing the fire a little, fufes, is poured out upon a copper-plate, in the form of little oblong bars, and kept clofely ftopped up in glafs bottles. In this manner is the *cauftic alkali* prepared, either of the *mineral* or common *vegetable* alkali. But when the *common cauftic* of the fhops, (*Lapis caufticus Chirurgorum, Cauterium potentiale*) is to be prepared from this falt, it is fufed in a red-hot crucible, in which ftate at firft it boils up and effervefces a little, but by degrees fubfides again to the bottom, and fufes gently and tranquilly, in the form of an oil of a blood-red colour. Upon this it is poured out into an iron mould, which gives it the fhape of flender fticks, which muft be kept from the accefs of the air, in bottles, made warm and clofe ftopped up. The refult of this operation proceeds from the circumftance, that the burned lime, during its calcination, has loft its aerial acid; and, on the other hand, has been replenifhed with the pure matter of fire; but that the alkaline falt is poffeffed of a large portion of this acid, which, having a greater affinity to the calcareous earth, more eafily unites with it. Now therefore when thefe two bodies meet, the aerial acid firft quits the alkali, and takes poffeffion of the calcareous earth; but the inftant that this happens, the matter of fire flies off alfo from the latter, and unites, on the other hand, with the alkali now bereft of its fixed air. Confequently, in order to enable all the aerial acid to fly off from the alkali, as much quicklime muft be added, as is capable of taking up the whole of this acid. But in the fame quantity of good lime there is contained as much matter of fire, which is expelled by the fixed air in its paffage into the lime, as can be combined with the alkali now bereft of this air. In this exchange of conftituent parts there fubfifts moreover another caufe of the following phenomena, viz. that the remaining calcareous earth now effervefces with acids, and ceafes to generate heat; and that, on the other hand, the alkali no longer effervefces with them, but generates heat. This is directly the contrary of the former effects of each fubftance*. The fame effect might perhaps be produced upon fixed alkali merely by

* In explaining thefe effects there feems to be no neceffity for fuppofing either the prefence of the matter of fire, or the action of a double decompofition: the great difcoverer of the aerial acid, as it is now called, having, from the very firft promulgation of his doctrine, given it as his opinion that

by expoſing it to a red heat, if we had crucibles capable of retaining this ſalt in the fire long enough in its increaſing ſtate of acrimony.

Fixed alkali increaſes in acrimony likewiſe, even when it is only fuſed with different phlogiſtic bodies by a briſk fire: in an intenſe fuſion for inſtance, with the addition of powdered charcoal or other ſuch ſubſtances; on occaſion of which however it is ſtill dubious, whether in ſuch caſes the phlogiſton be combined with the alkali in its intire ſtate; or whether it be not rather decompoſed by it, and only the pure matter of fire united with it. From this very cauſe alſo proceeds the alteration which nitre undergoes when expoſed together with the martial regulus of antimony, to a red heat. The conſequence of this is, that the nitre by the phlogiſtic part of the metal that is added here, loſes its acid by virtue of a decompoſition which takes place in it, and the remaining alkali acquires the higheſt degree of acrimony. For this purpoſe theſe two bodies are wont to be combined in different proportions. But it is inconteſtible, that there is no better proportion nor proceſs than that recently deſcribed by Dr. *Dehne*. In this, four ounces of well purified regulus of antimony are mixed with eight ounces of depurated nitre, and ſet upon the fire in a large crucible. This mixture is kept for the ſpace of an hour, in a very ſtrong fire; then four ounces more of nitre are added, and kept upon the fire an hour longer, upon which again four ounces of nitre are added, and the whole urged with a red heat during the ſpace of another hour, when the laſt four ounces of nitre are put into the crucible; ſo that twenty ounces of nitre are conſumed in the ſpace of four hours. In the beginning of the operation the matter is hard and of very difficult fuſion; by the gradual addition of nitre it is rendered continually more and more fuſible, and apt to expand, ſo that towards the end, when the whole maſs occupies above one third of the crucible, great care muſt be taken to prevent it from flowing over. But when at length the effervefcence of the maſs has ſubſided again, the proceſs muſt be continued with the moſt vehement fire of a wind-furnace, till the maſs fuſes quite tranquilly in the crucible, and becomes as fluid as water. It is now to be poured out, and has a greeniſh ſemi-tranſparent appearance, and without doubt conſtitutes the moſt fiery alkali that it is poſſible to make. With this maſs the very beſt *tincture of antimony* is prepared, by bruiſing it directly while it is hot, and pour-

that the changes abovementioned are effected by a ſingle elective attraction, and that the cauſticity of lime and alkalies proceeds from their being in a pure and uncombined ſtate; a doctrince ſince ably ſupported and enlarged upon by M. *Macquer*, in his Chem. Dictionary. [E]

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ing upon it from three to four pounds of very ſtrong ſpirits of wine made a little warm. The pulveriſed maſs grows hot, and at the ſame time heats the alcohol, on this occaſion, as violently as quicklime when ſlaked with water. The ſpirit immediately becomes as white as milk, and after a gentle digeſtion, acquires an opaque blood-red colour. The reſiduum, at the end of the operation, when the tincture is extracted, very much reſembles the common brittle reſin.

For obtaining the abovementioned highly cauſtic ſalt in perfection, the following particulars muſt be obſerved: 1. that the martial regulus of antimony be fuſed ſo long with nitre till the ſlags become like amber, and tranſparent: 2. that the nitre be perfectly purified: 3. that a ſufficiently capacious crucible be employed on account of the riſing and ſwelling of the materials, and that it be kept conſtantly covered during the fuſion: 4. that the nitre be added ſlowly in order that both the nitre and the regulus of antimony be not decompoſed too violently; and that the greateſt part of the phlogiſton be not ſo forcibly expelled, as when the whole mixture is expoſed to the action of the fire. Finally: 5. it is an eſſential requiſite, that the fire be increaſed in ſuch a manner, that the two bodies may exhibit the mutual action of their ſubſtance upon each other, by effervefcing: and 6. the fuſion be continued for ſo long a time, till at length the whole maſs fuſes quietly in the crucible, and becomes fluid like water; for a long-continued fuſion is the principal object to be attended to in this operation*.

In order to explain the circumſtances which occur in this operation, it muſt farther be obſerved, that the large portion of nitre here introduced, which however is done by degrees, acts upon the regulus of antimony by its acid; and diſſolves it by the vehemence of the fire; and that as well the phlogiſton which is deeply enveloped in the regulus, as that which exiſts in its own compoſition, is at length moſt intimately combined with its remaining alkali, from which the above-mentioned *moſt fiery ſalt* ariſes. Now when we farther conſider that ſpirit of wine undoubtedly contains oily particles; that cauſtic ſalts in all caſes attack theſe particles with great force, and that, finally, the matter of fire in particular acts upon them to ſuch a degree as to impart a dark colour to them; as

* More concerning this ſubject may be ſeen in Dr. *John Chriſt. Conr. Dehne's Verſuche einer vollſtandigen, &c.* or *Eſſay towards a complete Treatiſe on the acrid tincture of regulus of Antimony, &c.* Helmſtadt 1779, 8vo. the 2d. Edition, Helmſtadt 1784, 8vo. [A]

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indeed this very effect of the action of fire is very viſible in empyreumatic oils; and when we beſides reflect upon the nature of the above-mentioned ſalt, which is highly impregnated with the matter of fire; we ſhall eaſily be able to account for the origin of the uncommonly dark-red colour, and the very great corroſive power of the antimonial tincture which is prepared from this ſalt. The more fiery conſequently ſuch a ſalt is, and the more oily particles are proportionably contained in the ſpirit of wine, the darker ſuch tincture muſt neceſſarily be. When in the ſame manner one part of what is called the regulus of metals, and which is deſcribed farther on, is fuſed with three parts of nitre, and a tincture is extracted from it with alcohol, it bears the name of *tincture of metals*, or *lily of Paracelſus*.

Upon a ſimilar impregnation of fixed alkali with phlogiſton, depends alſo the preparation of what is called the *lixivium of blood**. For which, according to the formula given by *Marggraf*, one part of pure fixed alkali, and two parts of bullock's blood well-dried, are put into a good crucible, ſo that one third of it ſhall remain empty. This crucible is put into the fire, and the maſs calcined till ſuch time as neither flame nor ſmoke is any longer to be perceived. Upon this ſome of the maſs may be taken out of the crucible for a trial, and diſſolved in a little water, in order to ſee whether it ſtill looks yellowiſh, and whether it ſtill precipitates ſilver of a browniſh or blackiſh colour. If it ſtill exhibits theſe properties, the maſs ought to be kept in a red heat, till it ceaſes ſo to do. The maſs is then poured out of the crucible, and when it is become cool, diſſolved in once and a half as much water as the alkali amounted to in quantity, and the liquor is filtered. Inſtead of blood, not only other inflammable parts of animals, ſuch as ſhavings of horn, bones, hair, wool, leather and many others, or the coals produced by the charring of theſe ſubſtances, but alſo the inflammable parts of

* And by *Bergman*, though ſomewhat improperly, *phlogiſticated alkali*. Various have been the propoſitions lately advanced concerning the compoſition of this ſubſtance. *Scheele* thought himſelf warranted by his experiments to aſſert that it conſiſted of pure fixed alkali united with aerial acid, volatile alkali and iron. But the conjecture of M. *Berthollet* is much more probable, viz. that it conſiſts of alkali united with mephitis and charcoal, (or rather the vegetable principle) to which may be added a ſmall quantity of iron. M. *Weſtrumb* of Hamel in Saxony, is firmly of opinion that this alkaline reagent contains the phoſphoric acid: and has adduced in the *Chemical Annals* many experiments in proof of his opinion, which however are not deciſive. [E]

vegetables and minerals may be employed, ſuch as ſoot, ordinary charcoal *, reſins and bitumens; though animal ſubſtances are always to be preferred.

From the different phenomena which are obtained in this preparation, as alſo from many other obſervations, thus much is aſcertained, that in it an inflammable matter, with which a volatile alkali is moſt intimately united, is copiouſly combined with fixed alkali; along with which compound, at the ſame time, a ſmall portion alſo of iron, which is contained enveloped in the blood, or in the other ſubſtances employed in the preparation of this ſalt, is taken up. Conſequently the lixivium of blood is a highly phlogiſticated alkali compounded by art, the principal uſes and application of which ſhall be mentioned in another place. Alkali moreover may in another manner be put in the ſame ſtate in which it exiſts in the lixivium of blood, by triturating to a fine powder one ounce of dark-coloured Berlin blue, and boiling it with from three to four ounces of a ſtrong ſolution of fixed alkali, till all the blue colour of the former is vaniſhed, upon which the liquor is to be ſeparated, by paſſing it through a filter †.

In order to combine the *volatile alkali* alſo with the pure matter of fire, and by this means put it into a cauſtic ſtate, it muſt be in like manner previouſly deprived of its fixed air, before the matter of fire can be united with it. Now this can be effected by ſuch bodies only as are impregnated with the matter of fire; and which conſequently muſt be in a pure or cauſtic ſtate, and at the ſame time poſſeſs a ſtronger affinity to the aerial acid. Above all others, quicklime is the fitteſt for this purpoſe. With this view thirty-ſix ounces of water may be poured upon twelve ounces of quick-lime in a veſſel of ſtone-ware, in order to ſlake it; this magma when it is become cool, is put into a retort or matraſs, four ounces of ſal ammoniac reduced to a coarſe powder, are added to it, and from eight to twelve

* M. *Weſtrumb*, in order to prove that the phlogiſticated alkali contains phoſphoric acid, having ſhewn that the former is to be produced from charcoal, which ſubſtance he aſſerts always contains this acid, M. *Haſſenfratz*, in the *Journ. de Phyſique* for *July* 1787, in anſwer to this, allows, and indeed proves by experiment, that all the woods of which charcoal is generally made, as well as the charcoal itſelf, contain the phoſphoric acid; but at the ſame time ſhews that this acid is by no means neceſſary in the formation of cyanocratic neutral ſalts, or, as he terms them, *Pruſſiats*. [E]

† With reſpect to the property exhibited by the lixivium of blood, of depoſiting Berlin blue on the addition of an acid, vid. *Scopoli's* experiments with the dephlogiſticated alkali of lixivium of blood, in the *Neueſte Entd. in der Chemie*, Vol. VIII. pag. 3—6. A Chemical inveſtigation of dephlogiſticated ſalts, by L. *Brugnatelli*, in the *Chemiſche Annalen*, Vol. I, p. 197—207. 307—310.—*Scheele's* method of purifying lixivium of blood from iron, ibid. p. 525. *Weſtrumb's* method, ibid. Vol. II, p. 41. [A]

ounces of liquor drawn off from it, by diftillation with a gentle heat. Twelve ounces lefs of water alfo may be put into the retort, and replaced previous to the diftillation by the fame quantity of fpirit of wine. In the former cafe, it is fimply called *cauftic fpirit of fal ammoniac* (fpiritus falis ammoniaci caufticus); in the other, fpiritus falis ammoniaci caufticus vinofus *. In neither of thefe preparations, is any concrete volatile alkali produced. By this fpirit no precipitation is made either from a folution of calcareous earth, or of terra ponderofa in acids, or from lime water; neither does it effervefce with acids.—Inftead of lime, cauftic fixed alkali may be employed, but with lefs advantage. When minium is fubftituted to lime for the expulfion of volatile alkali from fal ammoniac, it likewife renders this falt cauftic; but then it will ftill effervefce a little with acids. A fimilar cauftic fpirit is alfo obtained in the preparation of the martial flowers of fal ammoniac, in the beginning of the procefs.

This effect alfo, which takes place in the exacuation of the volatile alkaline falts, depends upon the operation of a double affinity. The marine acid of the fal ammoniac, in confequence of its nearer affinity, enters into the airlefs calcareous earth, and expels the matter of fire from it, which now unites with the liberated volatile alkali, and makes it cauftic; but as lime poffeffes no aerial acid, and the volatile alkali from the fal ammoniac alfo has none of itfelf, it alfo can acquire none in this operation; confequently it is devoid of air, and juft for this reafon fit to take up the matter of fire. Of this theory, the circumftance of this falt being made cauftic by minium, exhibits a very convincing proof; with which too the revivification of calx of mercury by the mild fixed and volatile alkalies, obferved by *Weigel*, perfectly accords. The matter of fire which adheres to thefe falts, is, agreeably to the abovementioned principles, expelled from them again on the acceffion of the aerial acid, and reduces them to their priftine ftate. A fimilar effect takes place on the acceffion of acids, on which occafion the heat that is perceptible, and a fmall fcarcely vifible vapor, evidently prove to the fenfes that a matter of fome kind or other is making its efcape.

Volatile alkali may alfo be impregnated with phlogifton in its intire and undecompofed ftate, in fuch a manner that this former fubftance fhall acquire the fame property with regard to its effect upon iron in a ftate of folution, as the fixed alkali in the lixivium of blood, and therefore muft be confidered as a *volatile lixivium*

* By way of preventing the lime from adhering to the diftilling-veffel, from three to four ounces of common falt may be put into the veffel with the other ingredients. The former of thefe fpirits is called by *Sage*, *alkali fluor*. [A]



of

*of blood*. The firſt recipe for this was publiſhed by *Meyer*. Eight ounces of the mild watery ſpirit of ſal ammoniac are poured upon one ounce of dark Berlin blue, and digeſted with it till the blue colour is entirely vaniſhed, and the liquor has acquired a yellow hue like that of wine. The whole is then poured upon a filter, and the filtered liquor put into a retort, and about one third of it drawn off by diſtillation for the purpoſe of extracting the volatile alkali from it. A wine-coloured yellow liquor remains behind in the retort, which has a mild ſaline taſte, and precipitates any iron that is in ſtate of ſolution, of a blue colour. It contains phlogiſton, and even a ſmall portion of iron diſſolved in the volatile alkali. For the ſame purpoſe alſo cauſtic ſpirit of ſal ammoniac may be uſed.

When, in the combination of phlogiſton with different ſaline ſubſtances, the proportion of the former is very conſiderable, various other kinds of *combuſtible* ſalts occur alſo in the great ſtorehouſe of nature, which are plainly diſtinguiſhable from other ſalts by their actual inflammability. *Sugar*, *manna*, *honey*, and *ſugar of milk* are the moſt known ſpecies of this diviſion; which, on account of their ſweet taſte, form the firſt claſs. To the ſecond claſs I refer the *ſaline cryſtallizations formed in ethereal oils*.

*Sugar* is a very well known ſweet eſſential ſalt, the proximate conſtituent parts of which are a quite peculiar acid, phlogiſton in great abundance, and ardent ſpirit; but with reſpect to its remote conſtituent mixture, phlogiſton, a great quantity of water, and a little earth are diſcovered in it*. In its natural ſtate it is enveloped in a great many acido-ſaline mucilaginous particles of the juices of certain vegetables, from which it muſt be diſengaged by a neceſſary artificial proceſs, which chiefly conſiſts in obtunding the ſuperabundant acid, and in the ſeparation of the ſalino-mucilaginous compound. It manifeſts its ſaline nature as

* M. *Lavoiſier* ſeems to think that ſugar conſiſts of charcoal, inflammable gas, and an oil; of which the laſt is contained in it in a very ſmall proportion. His experiments have proved the preſence of inflammable gas in this ſubſtance beyond all contradiction; and though there is certainly no charcoal in it, yet it evidently contains in large quantities a principle belonging to charcoal in common with all vegetable ſubſtances; as is manifeſt from the fixed air it yields in diſtillation and fermentation. As for the oil, Mr. *Woulfe's* experiments rather perſuades us, that it is contained in ſugar in large quantities. In the Journ. de Phyſique for May 1788, this excellent chemiſt has ſhewn, that if gums, ſugar, honey, &c. be diſtilled alone, they yield phlegm, acid, and a ſmall quantity only of oil: but having added to gum arabic $\frac{1}{4}$ of ſalt of tartar, he procured a conſiderable quantity of oil, and the liquor that came over with it, was not acid, ſo that in all probabillity the inflammable gas that M. *Lavoiſier* obtained by the diſtillation of this ſubſtance, proceeded entirely from the oil contained in it, which Mr. *Woulfe* obſerves

as well by its cryſtalline form as by its great ſolubility in water, and its ſweet taſte. Its inflammability ſhews that it contains phlogiſton, and its diſpoſition to fermentation indicates the great quantity of air that enters into its compoſition; and indeed it is by this proceſs likewiſe that its ardent ſpirit is produced. It is ſoluble in ſpirit of wine in ſmall quantities only.

Without doubt ſugar was known at a very early period, as appears by a paſſage in *Dioſcorides* *, from which at the ſame time may be gathered, that at firſt, and perhaps indeed for a long time after the firſt diſcovery of it, it was only uſed as a medicine. From the ſame paſſage alſo may be inferred, that ſugar was only hiſtorically known to this Greek phyſician, and that conſequently in thoſe times neither the Greeks nor the Romans uſed it in its ſaline form. Long after him, in the time of *Paulus Aegineta*, who lived about the year 625, we find the honey or juice only of the cane (mel arundinaceum) uſed: on the other hand, *Rhaſes*, *Avicenna*, and *Meſue* had alſo already employed ſugar itſelf in various medicinal preparations. It is probable that the juice of the ſugar-cane was merely boiled down in the beginning of the diſcovery, till the art of refining it was diſcovered, which is ſcarcely four or five hundred years ago.

From the *ſugar cane* therefore (ſaccharum officinarum, *L.*) which in different parts of the Eaſt and Weſt Indies is cultivated in a moiſt ſoil, we obtain the ſugar

ſerves, is decompoſed by the acid in this operation, and charred. Inflammable gas therefore ſeems to exiſt in this ſubſtance as a *remote* principle only, and as forming the oil, which, and the vegetable principle (or what M. *Lavoiſier* calls charcoal) appear to be its *proximate* principles. But oils themſelves are compoſed, according to the ſame philoſopher, of inflammable gas, and this carbonaceous [or rather, if I may be allowed the expreſſion, carbonizable) principle. In this view of the ſubject, ſugar differs from oil only in containing a larger proportion of the vegetable or carbonaceous principle; and oil differs from charcoal chiefly inaſmuch as the latter does not contain inflammable gas, which the oil parted with on being burned or charred.—It ſhould be farther obſerved from Mr. *Woulfe*, that by repeatedly diſtilling the alkali with the gum, the alkali may be ſaturated with the acid of the gum. vid. l. c. [E]

To conſtituent parts ſomewhat ſimilar to the abovementioned, M. *Haſſenfratz*, (Journ de Phyſique, Avril, 1788) adds the baſe of pure air, probably in order to account for this ſubſtance fomenting with water in vacuo: but its decompoſition of water is ſufficiently accounted for by the degree of heat that is neceſſary to put it into action. The conſtituent parts of ſugar, according to this Chemiſt are, (to uſe his own words) " le muqueux combiné avec peu d'oxigene, & accidtellemont avec une certaine portion d'hydrogene."

* De Medicinali Mat. Lib. II. cap. lxxiiii. De Melle. Eſt et aliud concreti mellis genus, quod *Saccharon* nominatur. In India vero et felici Arabia in arundinibus invenitur. Salis modo coactum eſt, dentibus, ut ſal, fragile. Alvo idoneum et ſtomacho utile, ſi aqua dilutum bibatur; vexatæ veſicæ renibuſque auxiliatur. Illitum ea diſcutit, quæ tenebras oculorum pupillis effundunt. [A]

that

that is in common uſe. The canes are tied together in bundles, and the juice preſſed out in mills between rollers. As it paſſes to fermentation with extreme rapidity, it ſhould be quickly put into copper caldrons to be boiled, where it is clarified with lime-water, and boiled down to the proper degree of ſtrength. The ſubſtance thus inſpiſſated is then poured into large earthen moulds of a conical form, ſtirred about for a time, and afterwards ſuffered to ſtand undiſturbed till it becomes ſolid. Upon this, the lower plug of the veſſel is drawn out, that the liquor, which is ſtill contained in it, may be collected in other veſſels ſet underneath it. This is called *raw ſugar*, *muſcovade* or *powder ſugar*, which muſt be purified by farther refining.

The *refining* conſiſts of diſſolving the raw ſugar in water afreſh, and at the ſame time adding to it a quantity of lime-water with ſome bullock's blood, or, according to the Dutch method, the whites together with the yolks of eggs. After this it is made to boil, and ſtirred continually during the whole time, and the ſcum is taken off with a large perforated ladle. The addition of lime-water ſerves to remove a portion of the redundant acid of ſugar, which the raw juice, as well as the part of the ſugar that is not ſufficiently purified, ſtill contain, and which prevents the cryſtallization of the ſugar. There is no ſubſtance fitter for this than lime, becauſe it attracts the acid of ſugar in the moſt powerful manner, and at the ſame time forms with it a compound, of extremely difficult ſolution in water. When therefore this acid unites with the lime, the compound formed by their union is ſeparated in an earthy form, and is carried off in the ſcum. Conſequently the lime-water muſt be added in proportion to the acid that is preſent, which being done, there can be no calcareous earth left behind in the ſugar. The ſugar thus deſpumated is then filtered through a thick woollen cloth ſpread over a baſket, and once more boiled down with a gentle fire to the proper degree of ſtrength, or till it holds proof, and then, in order to cool it a little, transferred into a large copper cooler; finally, the moulds or pans being previouſly moiſtened well with water, are filled with this ſubſtance. During the time that the ſugar is cooling in theſe moulds, which now it does entirely, it muſt be thoroughly ſtirred very carefully three different times, which prevents it from coaleſcing in large cryſtals. When at length it is entirely coagulated, the full moulds are hoiſted up in large baſkets to the ſky-loft of the houſe, where the apertures at their lower points are opened, and ſo placed upon *melaſſes-pots*, that the melaſſes or treacle, which is ſtill contained in them,

them, may drain off. In order to promote this, the bafes of the cones or pans are covered to the thicknefs of feveral fingers breadth with an earth that been previoufly foftened by maceration in water, and which is now again moiftened with a little water; and this operation is repeated feveral times till the fugar has acquired the requifite degree of whitenefs. This is an admirable contrivance for cleanfing the fmall cryftals of fo deliquefcent a falt as fugar is, from the foul mother-water that adheres to them externally. For in the manner herementioned the fugar is wafhed, as it were, in the mould by the water that penetrates flowly into it, and finks gradually downwards, diluting all the while the uncryftallizable part of the melaffes, that it may the eafier drain off into the veffel underneath. Hence it is eafy to conceive, that for this purpofe an earth muft be employed of a particular kind, which will abforb water for a certain time, and part with it again flowly, and withal not contaminate it either with duft or any thing elfe. This earth, from the ufe to which it is applied, is called *Sugar-earth*, and confifts of a fandy, calcareous clay, which fhould be as near as poffible of a grey or white colour, and without any admixture of a yellow and fat earth.

The trifling portion of treacle, which cannot be entirely feparated, and which remains at bottom in the peak of the mould, is at length diffufed throughout the whole loaf, and rendered imperceptible by the mould being turned upfide-down, and fet upright on its broad part. When this end has alfo been obtained, the loaves are cleaned on the outfide, and perfectly dried upon frames in ftoves conftructed for the purpofe.

Since it appears from what has been mentioned before, that all loaf-fugar acquires the ftate in which it is ufually feen by a hafty and interrupted cryftallization, *fugar-candy* muft, on the contrary, be obtained by a very flow and undifturbed cryftallization. For this purpofe fugar, which has already been once purified, is depurated afrefh with fome lime-water, and, after being boiled down to the confiftence of a fyrup, poured into copper or brafs cryftallizing veffels conftructed for the purpofe, which are perforated all round with a great number of extremely fmall holes, and croffed in every direction with linen threads, and are befides pafted over with paper on the outfide, or by fome other means fecured, to prevent the treacle from running out. The veffels thus filled are at firft kept in a cool place for feveral days, and then conveyed to a ftrongly-heated ftove, where they remain undifturbed till the cryftallization is completed, after which the remaining treacle or melaffes is fuffered to drain off. Now, according to the degree in which

which the ſugar employed for this purpoſe has been purified, the cryſtallized ſugar will exhibit a *white*, *yellow*, or *brown* colour.

Well refined ſugar ſhould yield no precipitate, either by bare ſolution in water, or with lime-water, or alkali; neither ſhould it ſeparate a volatile alkali from ſal ammoniac, nor tinge the ſolution of ſublimate of mercury red. Loaf-ſugar muſt be dry, ſolid and ſonorous, tranſparent, beautifully cryſtalline and white.

From the ſcum, and all other impurities in theſe operations, another ſort of ſugar is prepared, firſt of all by boiling them afreſh, and then adding ſome lime-water to them; this ſort is called *baſtard* ſugar. The reſt of the impurities of the ſugar, which come into the water by waſhing the pans and other veſſels, and alſo all the foul water, in which the hands, frocks and aprons of the workmen have been waſhed, ſerve for no other uſe than to ſell to the diſtillers.

Beſides the ſugar-cane, many other vegetables alſo, as well indigenous as foreign, yield ſugar; and even if only a kind of melaſſes or ſyrup fit for uſe can be obtained from them, they are certainly worth attending to. Now, according to the obſervations of various naturaliſts, the following anſwer this purpoſe: *Skirrets* (Sium Siſarum); the *white Beet-root*, or *Mangold Wurzel* (Beta cicla, L.); the *red Beet-root*; the *Sugar Maple* (Acer Saccharinum); *common Maple* (Acer campeſtre); the *Icelandic Sugar-ſea-weed* (Alga marina); *Cows Parſnip* (Heracleum Spondylium); alſo the Agave Americana, or *Great American Aloe*, and the *ſveet Fucus*, or *Sea-belts* (Fucus Saccharinus). The proceſs is the ſame as for the other; and tends in like manner merely to the ſeparation of the ſweet ſaccharine ſalt and of the acid from the uncryſtallizable, mucilaginous juice.

*Manna* and *honey* likewiſe are to be conſidered as particular ſpecies of ſaccharine ſalts; but containing a larger portion of uncryſtallizable mucilaginous particles and acid, the ſeparation of theſe from them is more difficult than it is from the juice of the ſugar-cane. Add to this, that the common price of both theſe commodities is too high, to allow one to think ſeriouſly of putting a ſcheme of this kind into execution. Of the two, honey perhaps might be beſt employed for this purpoſe, as it appears to abound in ſugar, and ſmall ſaccharine cryſtals are very perceptible in honey that has ſtood for ſome time. If honey therefore was to be had in ſufficient quantity, and at a low price, it might perhaps pay the trouble and expence of making ſugar and treacle from it.

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The eſſential ſalt of milk, which is known under the appellation of *Sugar of Milk*, is made only upon the *Alps* in *Switzerland*. As it is ſold at ſuch an extremely cheap rate there, and as it may be had by the hundred weight at a time, it is hardly worth while to prepare it on purpoſe; eſpecially as it would coſt four times its preſent price to any one who ſhould prepare it himſelf. Nevertheleſs I will briefly mention the principal particulars of the preparation. For this purpoſe ſweet milk only is taken, which is turned with runnet, and in this manner freed as much as poſſible from all fat and caſeous particles. This ſweet whey is then evaporated till a pellicle appears, and cryſtallized in a moderately warm place. Upon the Alps, milk is decompoſed in this manner in great quantities, for the purpoſe of making cheeſe of it. By this means the inhabitants of the Alps get the ſweet whey for nothing, which they employ in the production of ſugar of milk, as an adventitious advantage. Sour whey, according to *Lichtenſtein*, yields quite an acid ſalt, which however by the addition of calcareous earth, may be freed from the acid that adheres to it, and converted into a perfect ſugar of milk *.

The other kinds of inflammable ſalts, are thoſe concretions which are ſometimes found in ethereal oils, in a cryſtalline form. Theſe however do not belong to the ſaccharine ſalts, but ſeem rather to form a particular claſs among the inflammable ſalts. Though ſome chemiſts conſider them as being different ſpecies of camphire, I am ſtill of opinion, that there are more reaſons in favour of their conſtituing a particular kind of oleaginous ſalt, as yet unknown. *Kunkel*, if I am not

* *G. R. Lichtenſtein's* Treatiſe on Sugar of Milk and its different kinds, *Brunſwick*, 1772. 8vo. German. [A]

For a more accurate analyſis of this ſubſtance we are indebted to thoſe ingenious Chemiſts Meſſrs. *Scheele* and *Hermbſtadt*. The latter has ſhewn that the ſugar of milk conſiſts of acid of ſugar, of which ſome part is combined with calcareous earth; while another ſtill greater part, being united with mucilaginous particles, conſtitutes that reſemblance which this ſalt has in ſome degree with ſugar itſelf. [D]

In this caſe, I ſhould rather ſay that the ſugar of milk does not differ from that of the ſugar-cane, otherwiſe than in being mixed with a certain quantity of calcareous ſaccharochrate, or of a ſalt compoſed of lime and acid of ſugar, which latter ſubſtance may have been produced by the fermentation of the ſaccharine part of the food taken into the animal's ſtomach: for milk appears to be little elſe than unaltered chyle.

But *Scheele's* experiments indicate that ſugar of milk contains an acid ſui generis, which we have called the Galamelitic acid: and M. *de Morveau*, in the Encyclop. de Chemie, has endeavoured to ſupport this opinion, and to prove that M. *Hermbſtadt's* own experiments likewiſe, inſtead of overthrowing it, ſupport it. [E]

miſtaken, was the firſt who directed the attention of Chemiſts towards this phenomenon, as he mentions a cryſtalline maſs of this kind, which had concreted in oil of roſemary, and which he conſidered as a ſalt. *Slare* obſerved a ſimilar concretion in oil of cinnamon; *Cruger* and *Geoffroy*, in oil of *marjorum*; *Maud*, in oil of *ſaſſafras*; *Neumann*, in oil of *thyme*; *Walther*, *Pabitzſki* and *Dehne*, in oil of *parſly*; *Geoffroy*, likewiſe in oil of *turpentine* and *feverfew*; *Gaubius*, in *Curaçao oranges*; *Bucholz*, in oil of *juniper*; *Tromſdorf* obtained it from the *flowers of cinnamon* (flores caſſiæ); and *Heyer* from the *pulſatilla* (anemone pulſatilla). Beſides theſe, I am myſelf in poſſeſſion of ſpecimens of this ſalt from the oils of *mace* and *dill*.

In conformity to ſuch a number of obſervations, this peculiar genus of ſalt is probably to be ranked among thoſe conſtituent parts of vegetables which have been long neglected. Its chief properties are as follow: 1. the ſmell and taſte is mild, and in every reſpect reſembles the body from which it has been obtained: 2. it has a cryſtalline form, which however is different in each ſpecies: 3. it fuſes by heat, and is inflammable in the fire: 4. it is inſoluble in cold, but ſoluble in hot water: 5. it is equally difficult of ſolution in ſpirit of wine: 6. likewiſe in ethereal and expreſſed oils: 7. after cooling, it cryſtallizes afreſh in whatever liquor it is diſſolved. If theſe cryſtals were camphire, they ought to be totally inſoluble in water, but eaſily and copiouſly ſoluble in ſpirit of wine and oils, and even to remain united with ſmall portions of them; but as they exhibit quite the contrary appearances in every reſpect, are ſoluble in boiling water, unite with difficulty, and that only in a ſmall quantity with ſpirit of wine and oils, and moreover are quickly ſeparated afreſh from them by cryſtallization; I apprehend theſe reaſons are ſufficiently cogent to induce one to conſider cryſtals endowed with ſuch properties, as a peculiar kind of oily inflammable ſalts. I do not however pretend, on this account, to deny the poſſibility of the exiſtence of different kinds of vegetables which may contain real camphire; in this caſe it muſt neceſſarily be diſtinctly diſcriminated from the ſaline cryſtals abovementioned, by the requiſite properties. The flowers of Benzoe probably belong to this ſame claſs; but as they have already been mentioned before among the acid ſalts on account of their being more evidently of an acid nature, I paſs over them here.

As to the origin of theſe peculiar oleaginous ſalts; whether they are naturally already preſent in the different vegetable bodies in which they occur, but in a

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a latent ſtate and enveloped in the ethereal oils of theſe bodies, till by the eſcape of the volatile parts they are ſo changed as to be enabled to ſeparate from them? or whether they are formed in the oils themſelves in proceſs of time only, being compounded of certain conſtituent parts exiſting in theſe oils? Of theſe two propoſitions, I think I am able to affirm the former; becauſe in the ſeeds of parſly, the flowers of cinnamon, and the pulſatilla we have manifeſt inſtances of ſimilar oleaginous ſalts appearing in a ſhort time after their being diſtilled with water. On the other hand, the long time which they require in order to extricate themſelves from different ethereal oils, may probably depend on the too great affinity of the ſaline to the oleaginous particles, and therefore a long time may be required, before they can coaleſce into maſſes, and cryſtallize.

Finally, we ſhall now proceed to the deſcription of *Soaps* and *Saponaceous* bodies; by which terms are underſtood ſuch ſaline compounds, as are formed from unginous and inflammable bodies, which not being ſoluble in water by themſelves, compoſe by the aſſiſtance of ſalts, a homogeneous maſs, ſoluble in water. Theſe ſubſtance are ſlippery to the touch, and ſoluble in water and ſpirit of wine, and commonly lather and froth with theſe fluids, upon being agited with them; and alſo render ſeveral other ſubſtances miſcible with water. They are diſcriminated from each other, not only by the various ſalts, but likewiſe by the different ſorts of fat ſubſtances employed in their preparation. Similar combinations alſo are found ready formed in nature, though theſe are leſs in uſe, and require to be adapted by art to the different purpoſes, to which they may be applied.

Different vegetables very evidently exhibit by *nature* a ſaponaceous quality in their compoſition, of which ſoapwort, the ſoap-berry tree (Sapindus ſaponaria), and the common night-ſhade, may be adduced as inſtances. Now ſince the period that we have been convinced of the preſence of alkaline ſalts in vegetables, nothing is eaſier than to conceive the origin of a mixture of this kind. In proportion therefore as this ſalt, and the oily parts exceed the reſt in quantity, and the force of the alkali is not weakened at the ſame time by the preſence of a mineral acid, ſuch vegetable will be more or leſs of a ſaponaceous nature. Sometimes alſo, though more rarely, a ſaponaceous compound is met with in vegetables, which conſiſts of oleaginous particles and an acid. For this reaſon, it is neceſſary in every caſe, previous to attempting to aſcertain the compoſition of one of theſe compounds, to ſee of what kind it is. With this view, the watery extract of the ſaponaceous

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plant needs only be mixed with a ſolution of fixed alkaline ſalt, and notice taken whether any precipitation or ſeparation of the conſtituent parts enſues or not. If in this operation the mixture is not obſerved to become turbid, but that an acid, on being added to it, produces this effect, it may reaſonably be inferred, that this ſaponaceous compound has an alkaline ſalt for its baſis. But if upon the addition of an acid to ſuch extract, no alteration enſues, and it is, on the contrary, rendered turbid by an alkali, it may be concluded, that the compoſition is ſaponaceous with an acid baſis.

*By art*, a perfect ſoap cannot be produced by means of *acids*. From the commixture of fluid acids and oily ſubſtances no other than greaſy, ſaponaceous maſſes ariſe at moſt, which, though they are miſcible with water, cannot however be brought into a ſolid and concrete ſtate, and at the ſame time preſerve their ſaponaceous qualities.

The alkaline ſalts, on the contrary, are the real and neceſſary intermediate ſubſtances by which all oleaginous, or other inflammable bodies may be brought into a perfectly ſaponaceous ſtate. But in order to promote the combination propoſed, they muſt neceſſarily be previouſly exacuated by the igneous matter of lime *. All ſaponaceous combinations, that can be made by this means, may be conveniently claſſed, according to the difference of the inflammable bodies of which they are compoſed, into *tallow*,—*vegetable-oil*,—*train-oil*,—and *ſulphureous-ſoaps*.

With the *fixed alkaline ſalts*, the mineral as well as vegetable alkali, *tallow-ſoaps* are prepared in the following manner: One part of eithrr of theſe alkaline ſalts and about two parts of quick-lime, or as much as is requiſite to render them perfectly cauſtic, are to be mixed together, and made into a ſtrong ley with the neceſſary quantity of water. This ley is then made to boil with three parts of tallow or fat over a gentle fire, and kept continually ſtirring, till the mixture becomes thick, and ceaſe to adhere to the hand, when a little is taken out of it for a ſample. Towards the end, a proportional quantity of common ſalt is added, by which the ſoap acquires a greater degree of hardneſs; becauſe the common ſalt attracting a portion of the water, which is ſtill contained in the ſoap, is diſſolved by it, and ſubſides to the bottom, as a ſtrong neutral ley. The weight of the ſoap here acquired is commonly double that of the tallow employed in

* Lime acts here by depriving the alkalies of the aerial acid with which they are generally (in part at leaſt) neutralized, and which prevents their union with the oils. The exiſtence of the matter of fire is not proved, and the ſuppoſition is needleſs. [E]

making

making it. In the ſame manner a *wax ſoap* may be prepared either of yellow or white wax, which is about three times the weight of the wax, is very hard and firm, and has an agreeable ſmell of almonds. The *Gravenhorſts* in Brunſwick likewiſe prepare a ſoap of cocoa butter for medical uſes. *Sperma ceti* alſo may be made into ſoap with a cauſtic ley *.

For the purpoſe of making *vegetable oil-ſoaps*, olive-oil, or oil of ſweet almonds, is treated in the ſame manner, till it acquires the requiſite hardneſs; of which the ſoaps of Alicant, of Venice, and other of the finer kinds of ſoaps may ſerve as inſtances. For the coarſer ſorts, lin-ſeed or hemp-ſeed oil is employed. Either of theſe kinds of ſoap, to be good, muſt not feel greaſy or unctuous in water, nor exhibit any veſtige of fat upon the water. It ought farther to diſſolve eaſily in water, and lather well, as likewiſe be eaſily ſoluble in ſpirit of wine. It muſt not become moiſt in the air, nor throw out a ſaline efflorеſcence on its external ſurface. When a ſolution of ſoap in ſpirit of wine is poured into river or ſpring water, a precipitation enſues, and a great part of the precipitate is no longer ſoluble in water. All ſoaps are decompoſed again by acids, and the fat matter ſeparated from them. The alteration however, which the fat and oils undergo on this occaſion, is very remarkable. They are now ſoluble in ſpirit of wine, whereas before the caſe was quite otherwiſe; the cauſe of which depends on the action of the matter of fire upon theſe bodies; and indeed the naked fire manifeſtly exerts the ſame effect upon them in ſuch caſes, in which it converts them into empyreumatic oils. In the ſouthern countries, mineral alkali, but in the northern countries, the common vegetable alkali is more commonly employed in the manufacture of ſoap. With mere lime-water a ſaponaceous greaſy mixture only, but no ſolid ſoap, can be obtained. Beſides the above-mentioned fat ſubſtances, a *reſinous ſoap* may alſo be made from the coarſer kinds of reſin with cauſtic ley.

Ethereal oils are not united to alkaline ſalts but with great difficulty. Hence *Starkey's ſoap* the only ſoap of this kind known. This ſoap is prepared by pouring four parts of oil of turpentine upon one of pulverized, highly cauſtic, fixed alkali in an alembic, digeſting them together for ſome time in a gentle heat, and laſtly, diſtilling the oil over the helm, and pouring it back again ſeveral times, till at length the ſalt will take up no more of it, and has acquired

* Chem. Journ. V. II. p. 133.

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a saponaceous nature. With empyreumatic oils, a combination of this kind has not as yet succeeded; the formation of a soap of *camphire* however succeeded perfectly well.

For *train-oil soap*, which occurs under the appellation of *black soap*, the oil of various kinds of marine animals is employed, such as whales seals, herrings, &c. From these can be prepared a greasy, soft soap only, of a dirty colour and a disagreeable smell, which is used in various processes in manufactories.

*Volatile alkali* is in its nature but ill adapted for remaining fixed in bodies till a perfect combination can take place with various kinds of fat; though in its caustic state, by bare mixture alone, it imparts a saponaceous quality to lard, butter, and fat oils, insomuch that they become soluble in spirit of wine. Consequently it is only capable of uniting with volatile ætherial oils, from which concrete and fluid, volatile, oily salts are compounded. Of the former kind is, what is called in Germany, *English Smelling-salts*, which is sublimed from dry, volatile salt of sal ammoniac mixed with a scented oil. Otherwise it may be expeditiously, indeed extempore, by a mixture of three parts of purified alkali, one part of pure sal ammoniac and an addition of one or more parts of scented etherial oils ad libitum, and kept in a phial well stopped, In the main too, the salt of hartshorn above-described resembled resembles this. Of liquid, volatile, oily salts, the empyreumatic, urinous spirits, *Sylvius's volatile spirit* (sal volatile oleosum Sylvii), likewise what is called Eau de luce, may be considered instances. For the latter, in two drachms of the strongest alcohal are dissolved from six to ten drops of rectified oil of amber, and afterwards one scruple of white soap; this mixture is then poured into an ounce of the caustic spirit of sal ammoniac, and the whole well shaken together.

* Under the appellation of *sulphureous soaps* are understood those combinations which otherwise occur under the very improper denomination of *livers of sulphur*, and consist in a combination of sulphur with an alkaline salt. They are of different kinds. In the moist way is produced an *earthy liver of sulphur*, by boiling sulphur with quick-lime. But more perfect than this, and the most common of any is the *saline liver of sulphur*, which is obtained by the fusion, on a gentle fire, of three parts of purified mineral or vegetable alkali triturated to a fine powder, and mixed with one part of pounded sulphur. This combination however is most perfectly effected by means of the caustic alkali. Sulphur is rapidly and

* Vide Neueste Entdeck, in der Chemie, Vol. XI. p. 113.

copiously

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copiously dissolved by being boiled in a saturated caustic lixivium. Some drops of this lixivium are used as a *wine-proof* for trying white wine (liquor vini probatorius), whether it be adulterated with lead, in which case a brown or a black precipitate ensues; whereas, on the contrary, a pure wine yields a white precipitate. It has lately however been shewn, that in several respects this method cannot be depended upon, since other substances likewise, which may be mixed in the wine, either accidentally and without any bad intention, and even without being in the least prejudicial, produce the same appearance with it. Now though this latter case happens but very seldom, yet it deserves to be attended to, since for want of paying attention to it, an innocent person might happen to be suspected of a crime deserving the most exemplary punishment. This probatory liquor therefore may still be used; only, for the sake of certainty, the dark-coloured precipitate, that is produced by its means, ought to be accurately examined, before it can positively be asserted that it is a precipitate of lead. Both sorts of liver of sulphur, especially when they have been prepared in the dry way, have a brown colour, a highly disagreeable taste, an odour like that of rotten eggs, and are soluble in spirit of wine. The sulphur is precipitated from them by acids.

Saline liver of sulphur is likewise an active solvent of most metals, especially in the dry way. It is therefore very conveniently employed for the separation of metals from their ores, from which the dissolved metals may afterwards be precipitated by other more ordinary metals, which bear a greter affinity to the sulphur. When the metals are already by nature mineralized with sulphur, nothing more is requisite for this purpose than to fuse them with fixed alkali. In this manner the *metallic livers of sulphur* are procured, of which the *liver of antimony* is an instance. The latter is usually obtained from equal parts of antimony and nitre, by setting the mixture on fire with a red hot coal. But it may be prepared full as well from one part of antimony and two parts of alkali by fusion in a red heat. From this latter mass, with alcohol, the common tincture of antimony is generally prepared; which however contains neither sulphur nor antimony, and is a mere alkaline tincture. In these metallic livers of sulphur the metal is dissolved by the hepar; when therefore an acid is poured into an aqueous solution of them, the acid, conformably to the degrees of affinity subsisting between them, unites with the alkali, and consequently the metal is precipitated combined with the sulphur. Upon this is founded the usual method of preparing the *sulphur* of

*antimony*,

*antimony*, which ſhall be treated of in another place. But if the acid be already combined with another metal, which is alſo combinable with ſulphur, this immediately unites with it; e. g. When the ſolution of liver of antimony is precipitated by a ſolution of vitriol of iron, a *martial liver of antimony* is obtained. When the ſaline liver of ſulphur is roaſted in an open and gentle fire, it loſes its phlogiſton, and a vitriolated tartar remains behind; but the earthy liver of ſulphur, in ſimilar circumſtances, leaves nothing behind it but a ſelenite.

With volatile alkali alſo, *Volatile ſulphureous ſoaps* may be compoſed; for which purpoſe, on account of the volatile nature of this ſalt, recourſe muſt be had to diſtillation. In this way, the mild volatile alkali takes up but a ſmall portion of ſulphur, for which reaſon it is neceſſary to bring it previouſly into a cauſtic ſtate by means of the igneous matter of the lime. An inſtance of this is *Beguin's ſpirit of ſulphur* (ſpiritus fumans ſulphuratus Beguini), which is juſtly conſidered by *Hoffmann*, as a *volatile tincture of ſulphur* (tinctura ſulphuris volatilis.) Conformably to chemical principles, the preparation of this requires eighteen ounces of quicklime, ſix of ſal ammoniac, and three of ſulphur, each ſeparately pulverized, then mixed together, and poured into a retort. After this, four ounces of water are added; the retort is ſhaken a little, put directly into the ſand-pot, and a capacious receiver inſtantly luted to it. The next day the diſtillation may be begun with a gentle fire, which however towards the end muſt be increaſed to a red heat, from which about eight ounces of a dark-yellow fluid is obtained. The cauſtic ſpirit of ſal ammoniac is even alone capable of diſſolving a portion of ſulphur with a gentle heat in the moiſt way. In other reſpects this tincture acts upon acids, and is acted on by them in the ſame manner as the liquid livers of ſulphur above-mentioned.

An inſtance of the *more compounded metallico-ſulphureous ſoaps* is exhibited in the following preparation, by which the *liquid ſulphur of antimony* (ſulphur antimonii liquidum) may be obtained. For this purpoſe an *antimonial ſoap* muſt firſt be prepared in the following manner: Two ounces of pounded antimony and one ounce of pulverized ſulphur are mixed together and boiled in an earthen veſſel with a quantity of cauſtic ley ſufficient to diſſolve the whole. To this decoction when filtered, are added ſix ounces of oil of almonds, or of fine and freſh olive oil, and the whole ſuffered to evaporate to a thick ſaponaceous conſiſtence in an earthen veſſel over a gentle fire. This, which conſtitutes the ſoap of antimony, is then digeſted by a gentle heat with twenty-four ounces of

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very weak ſpirit of wine, in ſtead of which, a pure malt ſpirit may be employed. In this proceſs I have deviated from the preſcription given by others; as by this addition to the ſulphur, the proportion of the liver of ſulphur is increaſed, and by its aſſiſtance the whole of the antimony muſt be diſſolved, and may be introduced into the ſoap.*

Beſides this, divers other *ſaponaceous bodies* are to be mentioned, which exhibit effects ſimilar to that of ſoaps upon ſubſtances and other bodies inſoluble in water, and make them at leaſt miſcible with it. This property *ſugar* exhibits with reſpect to ethereal oils, *almonds* in ſubſtance, the *yolk of eggs*, thick *mucilage* of gum arabic, Gum Tragacanth, the kernels of quinces, and mallow-root, upon Camphire, turpentine, wax, and different reſins; to effect which purpoſe, ſoap itſelf may be uſed with advantage.

* An account of more of theſe compounded, metallic, ſulphureous ſoaps is given in *William Henry Seb. Bucholz*'s Diſſ. de Saponibus quibuſdam Mineralibus. Jena, 1763, and Chemiſches Journal, Vol. VI. p. 169—183. [A]

## CHAP II.

### LITHURGY, or the OPERATIONS performed upon EARTHS and STONES.

THE ſubject of this chapter is all the bodies arranged under the claſs of ſtones, which by means of an acquaintance with chemiſtry, may be prepared and made uſe of for various purpoſes. Under this head likewiſe are comprized all theſe preparations, in which earthy bodies form the chief conſtituent parts. Here, without any regard to their different degrees of ſolidity, which make no difference in their chemical properties, earths and ſtones are conſidered, as being the ſame kinds of bodies, and only differing from each other with reſpect to the degrees of their hardneſs and coheſion.

All theſe ſubſtances are diſtinguiſhed from other unorganized bodies by their want of ductility, by their inſolubility in water, ſpirit of wine, oils, and quickſilver, by their fixity, and by their aptitude to be melted to glaſs. The major part of them poſſeſs theſe qualities, principally in a pure ſtate, but are altered by their combination with other ſoluble and volatile ſubſtances.

All earthy and lapideous bodies, ſuch as they are found in nature, may upon ſufficient foundation be conſidered as being compoſed of different kinds of earths, each of which again are frequently compoſed of the ſimple ſpecies of earths deſcribed before at p. 42 et ſeq. But manifold as are the earthy bodies derived from them, which occur in nature, they may nevertheleſs, upon the whole, from the ſimple ſpecies of earths of which they conſiſt, be diſtributed into five genera, viz. into *calcareous*, *ponderous*, (or *barytic*), *magneſian*, (or *murioecic*), *argillaceous*, (or *alumitic*) and *ſiliceous*, of the uſe of which we ſhall now treat.

Thoſe of the *calcareous* kind are in general rendered brittle, and friable by an intenſe, and continued red heat. The degree of hardneſs of the more ſolid kind is never ſuch as to ſtrike fire with ſteel; of which marble may ſerve as an inſtance;

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but when they contain a confiderable portion of filiceous earth in their compofition, they acquire a much greater degree of hardnefs by it, and fometimes will produce fparks of fire when ftruck againft fteel, as is known to be the cafe with feldt-fpar. They are fometimes met with native in the form of tranfparent rhomboidal cryftals, in which a foliated texture is obfervable, and then bear the name of *calcareous Spars*. This latter circumftance neceffarily fuppofes a previous folution of the calcareous earth in water, which may have been effected by the intervention of aerial acid. All calcareous earths and ftones effervefce more or lefs with acids, according to the greater or lefs quantity of calcareous earth they contain.

The pure *calcareous* earths effervefce very brifkly with all acids, and are completely diffolved by the major part of them. The effervefcence indicates the prefence of a great quantity of aerial-acid incorporated with them. The moft remarkable characteriftic property of this kind of earth is exhibited by the action of fire. In a continued red-heat, for the fpace of eight or ten hours they lofe all this aerial acid together with the water contained in them; while, on the other hand, the earth thus deprived attracts a confiderable quantity of the matter of fire, and keeps it in a loofe ftate of union for fome time. In this ftate the calcareous earth is called *burned Lime*, or *Quick-lime*. One hundred weight of crude calcareous earth by this means lofes nearly thirty-four pounds of aerial acid and eleven of water. But when calcareous earth is treated in a very long-continued and increafed red-heat, a lime that is ufelefs and of no value is obtained from it, called *over-burned* lime, and by the Germans *dead-burned*, the reafon of which probably is, that in this operation the matter of fire is more intimately united with the earth by the long-continued intenfe heat; and this latter is by this means brought nearer to a ftate of vitrification.

The properties of *Quick-lime*, obtained in this manner, are very different from thofe, which lime poffeffes in its crude ftate. In the ftate of quick-lime, when previoufly flaked with water, it is diffolved in acids without effervefcence, but accompanied with heat. In unflaked lime the heat is much ftronger, which however is not caufed by the acids employed, fince the fame heat is alfo excited by mere water, which in a great quantity of lime and a fmall quantity of water may be carried to fuch a degree, that other dry fubftances may be fet on fire by it. Under thefe circumftances a confiderable portion of the quick-lime likewife is

 diffolved

dissolved by the water; it possesses an alkaline taste, and also like alkaline salts, dissolves sulphur and fat unctuous bodies.

The saline quality of quick-lime, and its solubility in water, which proceeds from this quality, is probably derived from the matter of fire combined with this earth. This also seems to afford an explication of the well-known fact, that burned lime united by means of water with any of the various kinds of siliceous earth, produces a composition as hard as stone. The result of this latter operation is better known than its true cause. As far as we are able to penetrate into this subject, the burned lime, softened by the water, and divided as minutely as possible, penetrates into the smallest interstices of each grain of sand, composing the mortar, and is there indurated by the mutual attraction of particles, and made to unite in one common bond of union. Perhaps a minute solution of the siliceous, by the calcareous earth, contributes in some measure to the subsequent induration of this latter. The whole of the qualities peculiar to quick-lime must be imparted to it by exposure to a sufficiently strong red-heat, subsequent to which it must, by being properly slaked, be rendered fit for entering into the above mentioned union with the siliceous earth that is added to it.

The *Calcination* is managed according to the difference of the calcareous bodies in point of solidity. The harder lime-stones require a more violent and longer continued fire than the softer sorts. It is generally performed in an open fire; but in smaller quantities it may be accomplished with equal success in close vessels. In the operation in the great, the apparatus must be suited to the nature of the different combustibles used for fuel.

To effect this by a *fire accompanied with flame*, furnaces open at the top of an *elliptic* or *parallellopipedal* form, are used, in which are placed forms or benches, covered with lime-stones, and these are even vaulted over with the same, and the vacant places filled with them. The softer kinds of calcareous matter, which are in a more loose and powdery state, must be first kneaded up with water and moulded into the form of bricks, and then burned in the same manner.

On this occasion it is necessary to keep up an uninterrupted brisk flame, for which purpose all sorts of wood may be used, and in default of them, faggots of brushwood, heath, or other similar plants with strong woody stems, which are to be introduced by the fire-holes of the furnace, to maintain the proper degree of heat, and the flame of which passes through the interstices between the materials and the vent-holes. This operation must be continued, according to the degree of the heat, for twenty-four hours, and sometimes longer.

When

When fuel of fuch a kind is ufed, as affords merely a *weak* and *glimmering fire*, the calcareous earths made into cakes, and the lime ftones defigned to be calcined, are put together with the fuel in ftrata, into *inverted conical*, *femi-elliptic*, *tetra-gono-pyramidal* or *cylindrical furnaces*. Thefe furnaces are kindled at bottom, from whence alfo, when the requifite time is elapfed, the lime that is well burned, is taken out, and frefh lime ftones put in at the top. So that in this manner the calcination may be continued for the fpace of fix months together.

In this cafe, pit coals, peat, turf, and charcoal are ufed. With refpect to the coals, the pyritous and every fulphureous fort muft be avoided, becaufe the vitriolic acid, which exhales from them during the combuftion, will induce a change in the lime, which however, for fome ufes to which it is applied, perhaps may not be any great difadvantage to it. A previous privation of the fulphur they contain might be a means of preventing this inconvenience.* The purer bituminous fort of coals are always to be preferred; and in fuch circumftances alfo, care fhould be taken to feparate as much as poffible the earth of the fuel employed, which is apt to mix with lime-ftones, and which, without this precaution, efpecially the earth of the wood-afhes, would be of great detriment to the lime when this latter comes to be flaked with water. In fine, this method may, in many places, occafion a faving of expence, with refpect to fuel.

Inftead of lime-kilns or furnaces built on purpofe, heaps of crude lime-ftones may be piled up in the open air, and difpofed in layers together with the fuel. Still it will however be always more advantageous when the lime can be burnt by the heat of fuch furnaces, in which a violent fire is obliged to be kept up for other purpofes. This may be done either in brick-kilns or in the high furnaces ufed for the fmelting of iron.

The chief requifites of lime-ftones for making ftrong ferviceable lime that will bind well, confift, 1. in the choice of the pureft and moft folid lime-ftones, and 2. in keeping them long enough in a proper degree of heat. The requifite nature of crude lime-ftones is to be known by the degree of their folubility in acids. Such calcareous earths or lime-ftones, as are entirely foluble in acids, yield the beft lime; a worfe fort, on the other hand, is produced by thofe of which only about feven-eighths or three-fourths can be diffolved; but it is ftill more indifferent when no more than half of the crude earth is found to be foluble; finally,

* The author means that the coal fhould be charred, or reduced to *Coak*, as is done in this country. [E]

the

the worſt lime of all is obtained from ſuch, of which acids can only diſſolve one-fourth. The proper degree of fire for pure lime-ſtones is aſcertained by theſe criterions, viz. When the burned lime excites a briſk heat in water, is cauſtic to the taſte, and in flaking does not leave a hard ſtony nucleous in the middle. The phlogiſton, which is commonly met with in calcareous earth, cannot contribute any thing to the good quality of the lime, becauſe the beſt lime is burnt from the pureſt calcareous earths, in which a very ſlight quantity of phlogiſton can be proved to be preſent. The whole of the phlogiſtic compound * moreover is neceſſarily expelled during the intenſe and long-continued action of the fire, in which the phlogiſton could not poſitively have had any other effect upon the lime, than that of giving its pure matter of fire, to be attracted by the calcined calcareous earth; this on the other hand will be leſs capable of attracting the matter of fire from the fire itſelf to the point of abſolute ſaturation; which matter would without this have entered the lime very copiouſly. Beſides, ſuch an opinion is plainly contradicted by experience; ſince all phlogiſtic bodies, when mixed with lime, diminiſhes its cauſticity, unleſs they are calcined with it a freſh.

Upon the above deſcribed nature of the crude calcareous earth depends the whole difference of the quick-lime, which is obtained from the various bodies fit for this purpoſe. Pure calcareous ſpar, the ſhells of oiſters, muſcles, and eggs, as alſo pure chalk, yield the beſt lime, which is really preferable to the lime obtained from the different ſorts of marble and from the common lime-ſtones. This preeminence proceeds from nothing elſe than the purity of the calcareous earth. The heterogeneous earths that are mixed with the crude calcareous earth have moreover a peculiar influence upon the good quality of the lime; a portion of clay is more prejudicial to lime-ſtones than a quantity of gypſeous earth; and to lime-ſtones blended with the former ingredient ſo much the more detriment is done by a long-continued calcination, as by this means the argillaceous earth is the more eaſily diſpoſed to harden.

The

* M. *Wiegleb's* idea of phlogiſton is, that it is a compound body, conſiſting of the matter of fire and inflammable air. [E]

† When a perfectly pure calcareous earth is required for chemical experiments, one of the pureſt calcareous ſubſtance muſt be diſſolved in marine acid, and the ſolution filtered and precipitated with pure ſalt of tartar, or rather with volatile alkali. The precipitate muſt then be waſhed ſeveral times

The particles of fire, which, during the calcination, are united with the calcarous earth now deprived of its fixed air, are combined with it according to the laws of attraction, by which consequently their power of heating is suppressed, while they adhere to this earth, in the same manner as acids lose their peculiar properties as long as they are united with alkaline salts. Now, agreeably to this idea, the igneous particles that adhere to the calcareous earth must necessarily be liable to be separated from it again by the accession of such bodies, as have a nearer affinity either with the particles themselves or with the calcareous earth; in either of which cases the phenomena will be very different.

The former case occurs in consequence of the addition of *alkaline* salts, which, agreeable to the laws of affinity, yield their fixed air to the calcareous earth, and, on the other hand, unite with the particles of fire, and by this means become caustic, mention of which already has been made in the Halurgy.

For this reason it happens in the other case, that quick-lime, when exposed to the open air, attracts again their fixed air and water expelled by fire, which have a stronger affinity to the calcareous earth than the matter of fire has, and, on the other hand, parting with the latter, is converted into crude calcareous earth again. The case is the same with respect to water only, when poured upon quick-lime; on this occasion a violent hissing noise and incalescence ensues, the water which bears a greater affinity to the calcareous earth, uniting with it the matter of fire, which in all cases, when it subsists in a combined and aggregated state, manifests itself by heat, is by this means on a sudden, put into action; in consequence of which also the water poured on the lime in this operation becomes boiling hot. If this be done with as little water as possible, the incalescence will be so much the stronger, and likewise more particles will escape into the air. If, on the other hand, lime have such a quantity of water poured on it, as to be reduced, on being slaked to the consistence of porridge, the too rapid escape of the matter

times with boiling water, in order to deprive it, as much as possible, of all the salts adhering to it. At the same time care must be taken that the calcareous body to be dissolved contain no iron. [A]

It may be necessary to observe that by the epithet Pure, the author does not mean void of fixed air; on the contrary, both here and in many other parts of this work, he bestows this appellation upon earths and alkalies combined with the aerial acids, but free from the admixture of all other matters. Here in particular the observation applies; for calcareous earth cannot be precipitated from the marine or any other acid by what *Bergman* calls *pure*, and Dr. *Black caustic* volatile alkali; although it may by the *mild* (or aerocratic ammonium) by means of a double elective attraction. [E]

of

of fire, will by this means be prevented; and the lime will have thoſe qualities in perfection which it is deſigned it ought to poſſeſs. This operation is called *Slaking*, and the thin magma obtained on this means is called *ſlaked lime* *.

When in ſlaking the lime a greater portion of water is uſed, than is requiſite for that purpoſe; the water will diſſolve as much of the lime as it is capable of holding in ſolution, which amounts to nearly $\frac{1}{600}$ part. By this means is obtained *lime-water*, which is nothing elſe than a ſolution of ſlaked lime in water, and alſo poſſeſſes all its properties, though in a proportionate degree only. It diſſolves ſulphur, and makes alkaline ſalts cauſtic. The calcareous earth diſſolved in it is again precipitated conformably to the laws of affinity, by different intermedia. e. g. by the vitriolic, oxaline, and tartareous acids, and alſo by the alkaline ſalts. The air itſelf alone produces likewiſe the ſeparation. For whilſt at the ſurface of the water the matter of fire that is combined with the calcareous earth flies off, in conſequence of the air coming in to contact with it, the lime loſes all the properties it poſſeſſed as quick lime, and conſequently all its ſolubility †; hence the lime-water at firſt becomes turbid at its ſurface, upon which by degrees an earthly pellicle is formed, which is known under the appellation of *cremor calcis*, or *cream of lime*, and conſiſts of crude calcareous earth, which in theſe circumſtance has concreted in extremely minute cryſtals of calcareous ſpar ‡.

Quick-lime by itſelf undergoes the ſame change when expoſed to the open air, on which account it is eaſy to perceive a great difference between what is called *flour of*

* Mr. *Pelletier*, in the *Journal de Phyſique, Juin* 1782, mentions the following fact. Having ſprinkled a piece of well-burnt lime with water in the dark, upon falling to pieces, and being ſtirred, it was covered with fire, a phenomenon which ſtrongly confirms the preceding Theory. With this collate *Hermbſtadt's* experiments in the Chemical Annals, Vol. II. p. 40. *Lichtenberg*'s Magazine of the neweſt diſcoveries in phyſic and natural hiſtory, Vol. I. No. 4, p. 40. [A]

A ſimilar caſe is mentioned by *Meyer* in his "Treatiſe on quick-lime." All theſe facts may readily be explained, on the ſuppoſition of the lime either having retained ſome phlogiſtic particles, which could not be totally expelled in the burning; or elſe having acquired ſome from the fire itſelf in which it was burned, or even in the place where it was put after calcination. [E]

† This happens merely in conſequence of the air of the atmoſphere's containing aeriel acid, or fixed air. [E]

‡ As lime-water, that is poured off quite clear, is very apt to ſpoil; the better to preſerve it, ſome of the ſlimy ſediment that is formed in the making of it ſhould be put into bottles along with it.

*lime*, and lime properly ſlaked. Hence, likewiſe appears the neceſſity of preſerving the latter from the acceſs of air, when it is required to be kept for a certain length of time. For this purpoſe lime thus ſlaked muſt be buried in deep pits and covered up cloſe with earth; when it is called *buried lime*. With this precaution it might be kept for ten or twenty years, during which time it keeps conſtantly improving.

Calcareous ſubſtances, relatively to the mechanical treatment of them, and the uſes to which they are applied, are divided in a general manner, according to their different degrees of hardneſs and coheſion, into *mineral agaric*, or *guter*; *Chalk*, *calcareous Spar*, *common Lime-ſtones*, and *Marble* *. The ſuperiority of this laſt genus conſiſts in its poſſeſſing a finer grain, and a peculiar hardneſs. For cutting or grinding it, fine quartzoſe ſand is employed; and tripoli earth for poliſhing it. As marble is ſoluble in acids, the latter may be uſed for the finiſhing of ſtatues, and other pieces of ſculpture, formed of theſe materials.

The *mixed* kinds of *calcareous bodies* muſt be according to the nature of the ſubſtances combined with them.

Of the ſpecies of *calcareous ſubſtances that are mixed with the fluor acid*, the principal is *fluor-ſpar*. According to the experiments made by *Marggraf* †, and more particularly thoſe of *Scheele* ‡, it conſiſts chiefly of calcareous earth, and an acid of a peculiar nature (page 165.) It is true, in all theſe inveſtigations, a portion likewiſe of earth of alum has conſtantly been found in it; but this is conſidered as merely accidental. Should this latter earth be diſcovered likewiſe in perfectly pure cryſtals of fluor ſpar, we ſhould then be forced to admit it to be a real conſtituent part of this ſubſtance, otherwiſe inſtances ought to be adduced of the exiſtence of real native fluor ſpar, in which there is no earth of alum to be found. Of the fluor acid itſelf, all that is neceſſarily to be known has been mentioned already in the Halurgy. From the compoſition here attributed to it, and the acknowledged properties of each of its parts, it is eaſy to underſtand why this kind of

* All theſe are different combinations of pure calcareous earth or lime with aerial acid; and therefore although we cannot with M. de *Foucroy* conſider them as actual ſalts; they may be truly ſaid, as containing an acid, to partake of the ſaline nature, [E]

† Mem. de l'Acad de Berlin, T. XXIV. pour l'An, 1778, p. 3. [A]

‡ Trans. of the R. Acad. of Stockholm for the year 1771, as alſo *Crell's* Chem. Journal, Vol. II. p. 192. [A]

ſtone is ſo advantageouſly employed in the vitrification of other ſubſtances. Its external colour in all caſes is derived from iron, as accidentally forming one of its conſtituent parts.

*Calcareous earth combined with vitriolic acid* is found native in great abundance, and is called *Gypſum*, or *Plaſter*. The artificial preparation of this ſubſtance has been treated of more at large in the Halurgic Chemiſtry. This mixed kind of calcareous earth alſo occurs in nature, of very different degrees of ſolidity. It is found in a *pulverulent ſtate*, like *flour*, of which the *foſſil flour* diſcovered in the year 1709, in the neighbourhood of Reblingen, near Halle, and the *Himmel's mehl*, or *celeſtial flour*, (as it is ſuperſtitiouſly called,) which comes out of the ground, near Auerſtedt, may ſerve as inſtances. Sometimes it is met with in the form of ſpar more or leſs pure; ſometimes it occurs in the ſtate of a hard ordinary *plaſter-ſtone*; and others, in the form of very fine *Alabaſter*.

All ſorts of Gypſum are either completely ſaturated with vitriolic acid or not; hence ſome degree of effervefence with acids is obſerved in the latter,* which, with perfectly ſaturated gypſum is not the caſe; neither can it be diſſolved by acids in the ſame proportion as pure calcareous earth may. On the other hand, pure water diſſolves a greater portion of this than of pure calcareous earth. By way of ſhewing the natural compoſition of gypſum, water which has been boiled with it, may be mixed with a ſolution of alkaline ſalt, when the pure calcareous earth will be precipitated, while the vitriolic acid will remain united with the alkali. The reſult is the ſame, when equal parts of gypſum

* The *ſaturated Gypſum*, M. de *Fourcroy* obſerves, by calcination, affords only a fine plaſter; which makes an incoherent paſte with water, and is uſed for caſting ſtatues. This paſte, it is well known, is eaſily broken when dry; a circumſtance which depends on the maſs being alike throughout. This is not the caſe with ſuch plaſter as is proper for building. The ſtone which affords it at Montmartre and other places is a kind of breccia, formed of very ſmall granulated cryſtals of ſelenite, together with thin laminæ of calcareous ſpar. When this *unſaturated* Gypſum, as our author calls it, is burned, the ſelenite loſes its water of cryſtallization, and becomes friable; the calcareous ſpar at the ſame time being converted into lime by the loſs of its acid. In this ſtate it abſorbs water with avidity: and with regard to the ſolidity it ſo ſuddenly takes, it ariſes from the circumſtance, that when the quick-lime has abſorbed as much water as is neceſſary for its extinction, the ſelenite, which is interſperſed between its particles, cryſtallizes ſuddenly, and produces the ſame effect as ſand in mortar, by giving ſolidity to the whole. *Fourcroy*'s Elements of Chemiſtry. Vol. II. p. 202. [E]

reduced

reduced to a fine powder and of fixed alkali are mixed together, and either urged with a red heat for the ſpace of half an hour, and then boiled, or boiled immediately without being previouſly ignited; after which the calcareous earth appears detached from its former combination, which is now manifeſt by its effervefcing with acids.* A ſimilar decompoſition takes place when an ounce of powdered gypſum mixed with two drachms of charcoal in powder, is kept for the ſpace of ſeveral hours in a moderate heat. This maſs being afterwards boiled up with water, preſents the ſame phenomena as a ſolution of ſulphur in lime. All the different ſpecies of gypſum moreover contain a large portion of water of cryſtillization. When they are pulverized, and heated ſo intenſely in a ſtrong iron ladle over a moderately briſk fire, that the powder appears to boil, they loſe their water of cryſtallization in this calcination, and the powder, on being worked up with water to a thin paſte, acquires the property of attracting it again with avidity, and immediately forming with it a compoſition as hard as ſtone. But when gypſum is expoſed to a longer-continued and more violent fire, it entirely loſes this property of growing hard with water, (and is called by the Germans *dead-burned Gypſum)* the cauſe of which is by no means to be ſought for in the imaginary loſs of part of the vitriolic acid contained in it. For when *Beaumé* expoſed pounded plaſter-ſtone to a violent fire, in a glaſs retort, for the ſpace of four hours, in which operation the retort was nearly melted into one continued maſs, a quantity of perfectly inſipid water only, which neither altered the colour of the tincture of Litmus nor of ſyrup of violets, was obtained from it. But the reſiduary gypſum did not harden on the effuſion of water, and conſequently was over-burned gypſum †. This property therefore muſt rather proceed from a more intimate combination of the acid with the calcareous earth produced by the action of the fire. Farther, when gypſum is expoſed to a very violent and long-continued fire, like that in a porcelain-furnace, it melts, according to *Poerner*, to a real glaſs, in which operation, in all probability, the moſt intimate union muſt have taken place between the acid and the earth. From this the cauſe may alſo be deduced, why gypſum, which has been calcined ſeveral times,

* The alkali, in taking from it one acid, gives it another viz. the aerial in exchange, which is the cauſe of its now effervefcing on the addition of any ſtronger acid: for pure calcareous earth, i. e. lime, certainly effervefces with no acid whatever. [E]

† *Beaumé* Chemie experim. et raiſonné. Tome I. page 262.

is always leſs diſpoſed to become indurated by water. The hepatic odour too yielded by gypſum during its combination with water, gives riſe to a ſuſpicion that ſome phlogiſton may be contained in it.

The calcination in the great, may be performed by a gentle heat accompanied with flame, after the ſame manner as is done with the pure kinds of lime-ſtones; but for ſmaller quantities, the gypſum is pounded; to effect which purpoſe, the harder kinds may be previouſly burned, till they become rather friable; and the powder may be afterwards thoroughly calcined, keeping it continually ſtirring, till, as it is termed, *it is done*, or the ebullition has ceaſed.

The property of calcined gypſum, of being indurated with water, renders it fit for being applied to all kinds of ornaments in building, in which a ſudden exſiccation is requiſite. Another circumſtance, not leſs advantageous, is this, that a paſte of gypſum or plaſter does not ſhrink in drying, on which account it may be uſed for the fineſt moulds and the moſt accurate impreſſions. Of this ſubſtance likewiſe, *artificial marble*, of which ſlabs are formed, is prepared in the following manner: — A frame of wood is conſtructed of the length and breadth the ſlab is deſigned to be, and about two inches thick; which frame muſt however be ſo contrived, that it may eaſily be taken to pieces; on one ſide it is covered with a cloſe grained and ſubſtantial linen cloth, which is nailed faſt to the border of the frame. Upon this a ſufficient quantity of gypſum reduced to a fine powder is rubbed, and at the ſame time the colours intended for the artificial marble are prepared, each in a ſeparate veſſel; a ſufficient quantity of gypſum and ſtrong ſize alſo is mixed with each of them. A trowel-full of each of theſe mixtures is then taken, and put into a trough without any order, and without mixing them up together; upon which the maſs is only cut acroſs ſeveral times through and through with the trowel; hence ariſes a pleaſing irregularity and confuſion, ſimilar to that which is obſerved in real marble. The above-mentioned frame is then laid down in a horizontal poſition, with the linen ſide undermoſt, and filled with the quantity juſt mentioned of the gypſeous magma, and the whole left in this ſituation, till it is become perfectly dry. After which the frame is taken to pieces, and the ſurface of the table poliſhed, firſt with fine ſand and water, then with pumice ſtone, and laſtly with oil.

With regard to the good quality of gypſum or plaſter, much depends on its not being mixed with other kinds of earth, and alſo on its not containing unſa-

turated calcareous earth; next to this a ſufficient degree of earth is requiſite for its calcination, and pure water for the mixing up of the gypſeous powder. Of all the other kinds of earth there are none that poſſeſs the property of becoming indurated by water like gypſum; conſequently clay as well as the reſt of the earth would hinder the induration; and likewiſe water mixed with mucilaginous, oleaginous or ſaline particles muſt be contrary to the purpoſe. As the coheſion of the gypſum alſo depends upon the privation of its water by calcination, it is eaſy to conceive why the powder of gypſum loſes its power of coheſion after having been expoſed to the air for ſome time, and that it ought to be calcined but a ſhort time before it is uſed.

*Marle* is a ſpecies of earth, conſiſting of calcarous and argillaceous earth, and indeed properly deſerves this name only, when both kinds are contained in it in equal portions; ſo as that neither of them predominate in it. It is ſometimes of a ſpongy and earthy, and ſometimes of a hard and ſtony nature; the latter ſort, however, after ſome time falls to pieces in the air. In moſt kinds of marles, a portion of ſand is alſo found, which, however, in pure marle occurs in a ſmall quantity only, or even not at all. According to the different proportions of theſe parts, the ſorts of marles ſhould alſo be denominated by different additional appellations, In the calcareous marle, calcareous earth; in the argillaceous marle, argillaceous earth; and in the ſandy marle, ſand conſtitutes the largeſt part. The proportion of ſand may be diſcovered by waſhing the marles, and in the waſhed earth the proportion of the calcareous to the argillaceous earth may be aſcertained by means of the nitrous or marine acid. Calcareous marle yields but indifferent lime, on account of the argillaceous earth that is united to it; and on the other hand argillaceous marle, on account of the calcareous earth it contains, is unfit for pottery and bricks.

The earthy bodies that compoſe the ſecond claſs, viz. *the ponderous* or *Barytic* have an earth for their baſis, which is, it is true, in ſeveral of its properties ſimilar to the calcareous, but is alſo diſtinguiſhed by other very peculiar properties, whence it ought never to be conſidered as being a particular kind of earth. Pure ponderous earth combined with aerial acid,* is yet a rarity in nature. It is to be

* Called by *Bergman*, *aerated ponderous earth*, or, *aerated Barytes*: more properly, *Barytic aerocrate*; or, if not ſaturated with the acid (which is generally the caſe, eſpecially when native) *aerocratic Barytes*. Dr. *Withering*, of Birmingham, firſt diſcovered this earth in its native ſtate, and deſcribed it in the Phil. Tranſ. 1784. [E]

be known by its property of exciting an effervefcence with acids, by its eafy cryftallization after being diffolved in nitrous or marine acid, and by the other criteria given above. The ftate in which barytes is found in the greateft abundance is that in which it is combined with vitriolic acid, in which ftate it conftitutes the different kinds of *ponderous* or *heavy fpars*, and for this reafon it fhould be procured from them only. When barytes is wanted in a pure ftate, the heavy fpar muft be reduced to a fine powder, and two ounces, for example, muft be mixed with two and a half or three ounces of purified alkali, and urged with a red heat in a covered crucible for the fpace of an hour. The mafs is then to be triturated to powder, and boiled repeatedly with water, till there is not the leaft veftige of a faline tafte to be perceived. From this mixture, after exficcation, I have obtained an ounce and a half and two fcruples of powder. If it be required to be ftill purer, after being reduced to a finer powder, four or five ounces of weak nitrous acid muft be poured on it, till no more effervence is perceived. It appears in this operation as if the nitrous acid had not diffolved much of the earth; fince a confiderable quantity of earth remains undiffolved at the bottom of the veffel. We muft not however fuffer ourfelves to be deceived by appearances; but four times the quantity of diftilled water muft be added, and the glafs fet in a warm place, the clear liquor decanted, and frefh water added, when it will be found that the whole has been diffolved to within about half a drachm or two fcruples. From this folution, the pure earth may now be either precipitated with falt of tartar or volatile alkali, or evaporated and fuffered to cryftallize, which it eafily does. Thefe forts of fpar are diftinguifhed from the gypfeous and fluor-fpars by a greater fpecific gravity, and from the gypfeous fpars in particular by a more vitreous appearance, and by their not making good plafter when calcined, nor forming a complete folid mafs with water, phenomena, which are all to be derived from the peculiar nature of the conftituent earth. They are diftinguifhed from the fluor-fpars in their external appearance by a lefs degree of hardnefs, by a more obvious and coarfer foliated texture, and by the different form of their cryftals; but internally, by its peculiar earthy bafis and by the vitriolic acid; whence, when mixed with an inflammable body and by calcination, they are alfo capable of attracting the light like mere gypfeous fpars.

*Ponderous earth combined with calcareous earth* is difcovered and the nature and proportion of them determined by folution in the marine acid, and fubfequent cryftallization; becaufe ponderous earth only cryftallizes with it, but not the calcareous

calcareous earth. In *Cronstedt's Lapis hepaticus*, an instance of *terra ponderosa* combined with *calcareous earth* occurs, of which, according to *Bergman*, 100 parts consist of 33 parts of siliceous earth, 29 of pure barytes, or heavy earth deprived of fixed air*, five parts of earth of alum, and from three to seven of pure calcareous earth, besides water and vitriolic acid.

The different species of *Steatites* consist of such kinds of earths as are commonly soft and unctuous to the touch, almost like the argillaceous earths, and do not effervesce with acids; although at the same time their soluble parts are capable of being extracted by concentrated acids. They do not strike fire with steel, and may be cut with a knife. They have no ductility when steeped in water, but are commonly indurated in the fire. With respect to their composition, they consist of a very fine siliceous earth and magnesia; some sorts contain also a portion of phlogiston, and likewise some metallic parts. They may be distinguished into softer and harder sorts.

The earth which characterises and constitutes this kind of stone, is called *Steatitic earth*, *Talcy-earth* or *Magnesia*, has nowhere been found native in a pure state, or *combined* with *aerial acid* only; and on this account it has remained for so long a time unknown. When it is required pure, it must be first separated from the stone or earthy substance abovementioned, which however would be

* The author constantly expresses this idea by the epithet *luftleere*, which signifies *void*, or *deprived of air*. If this phrase were sufficiently accurate, its place might be properly enough supplied in our language, by the word *airless*; but the true idea to be expressed, is, "deprived of aerial acid," so that the term would be not only unusual and strange, but improper. On the other hand, the term, *caustic*, introduced by Dr. *Black*, though it may be applied with the strictest propriety to the alkaline salts, and some of the earths, is yet deficient with respect to three of these latter, viz. Silicite, Alumite, and Murioecite. We shall therefore in future employ the epithet *pure*, which is constantly used by *Bergman* in the same sense, and, though it may perhaps express too much, is, upon the whole, liable to fewer objections than any other yet invented. The Germans might perhaps aptly enough express this idea by the compound word *luft-saure-leere*; and in our tongue, which, with most of the other European languages, being farther removed than the German and Swedish, from the original Gothic Stock, does not admit of that facility and luxuriance of composition, we might adopt from the Greek the more harmonious, though equally significant term, *anaeroxyc*. Thus *anaeroxyc Barytes* signifies precisely Barytes or ponderous earth, void of aerial acid, and nothing more; whereas pure Barytes would insinuate that the earth is void of every thing; i. e. not only of aerial acid, but of phlogiston, and every thing else, even of specific heat or fixed fire, which notwithstanding is a favourite dogma with our Author and most of the German Chemists, and has not yet been absolutely disproved. [E]

very troublesome and expensive. It is obtained to the best advantage from Epsom salt, in the following manner: a quantity ad libitum of it is dissolved in twice, or rather, in three times its quantity of boiling water, and the solution filtered. At the same time an equal weight of pot-ash is dissolved in twice its quantity of boiling water, and filtered in like manner. Then, whilst both lixivia are yet warm, so much of the latter is gradually poured upon the former and kept continually stirred, till this is no longer perceived to become turbid; but the taste of Epsom salt, that it had before, is lost, and that of vitriolated tartar presents itself. Immediately after this the precipitate is poured upon a linen cloth, that the saline lixivium may drain from it; it is then taken and washed with as much water as is sufficient to deprive it of all saline particles. The first lixivia contain vitriolated tartar, but always carry likewise a part of the magnesia dissolved along with them, which is only to be separated by the evaporation of the lixivium *.

By being calcined for the space of two hours, this earth does not become caustic like calcareous earth; it only loses its aerial acid by this means, and consequently its property of effervescing with acids, and is indeed more difficult of solution in the acids than before; on this occasion likewise it loses about two

* M. *Butini* dissolves the Epsom salt in four or five times its weight of water, and the vegetable alkali in twice its weight of cold water, and exposes this latter solution for some months to the air. It is likewise poured cold into the solution of the Epsom salt, and the precipitate is washed on the filter with boiling water.

M. *Scheele* has shewn (in the Chemical Annals for 1787, Vol. I. p. 455) that if solutions of Epsom and common salts be mixed together, a double decomposition ensues, and the mixture now consists of Glauber's salt and muriatic magnesia, (or rather murioecic muria). In winter, previous to precipitating the magnesia, the Glauber's salt may be separated from this lixivium by crystallization. In summer, this does not succeed. The process is to be conducted as follows: Twelve pounds of Epsom and six of common salt are to be dissolved in a tinned kettle, in 27 *lb.* of boiling water; and not above one pound of the water evaporated. This lixivium must then be poured upon a canvas stretched over a frame, which is to be set in a cold place, where the thermometer stands at least three degrees below the freezing point. In the space of two days, a large quantity of Glauber's salt is found to have crystallized. The lixivium is then to be poured back again, the crystals washed with a little cold water, and this water to be added to the mother-ley. M. *Scheele* has obtained five pound and a half of Glauber's salt from the above quantity in this degree of cold; and in a much lower temperature, seven pound three quarters. The remaining liquor must now be diluted with water, and boiled: and during the boiling, the magnesia must be precipitated from it by adding an equal quantity, i. e. twelve pounds of fine white pot-ash dissolved in water, and strained through a sieve. The rest of the process is to be conducted as prescribed in the Swedish Pharmacopoeia. [E]

thirds

thirds of its weight. It is ufed in medicine under the name of *calcined Magnefia.* When this earth is thrown down from a folution of Epfom falt by cauftic alkali, a precipitate is obtained, which is fimilar to calcined magnefia, except that it may be diffolved in acids directly without effervefcence. From this it is evident, that this earth is in fome meafure altered by calcination. In its pure ftate it does not melt to a glafs. Although this earth does not become cauftic by a violent calcination, I am neverthelefs of opinion, that juft as in lime, the matter of fire is on this occafion united with it *.

Among the *fofter kinds* of *fteatitic earths mixed with filiceous earth,* which derive their origin from this, is the fubftance called *fpuma maris,* con-

* Compare with this, a paper written by M. *Weftrumb,* on the inflammation of calcined magnefia with vitriolic acid in the Chem. Annals, 1784. Vol. II. p. 432. [A]

All bodies generate heat in combining with each other, excepting in the cafe of diffufion and other circumftances of too complicated a nature to be inveftigated here. But if either of the bodies contain phlogifton, and the heat be ftrong enough, light likewife is evolved. Of this we have an inftance in the experiment referred to by our author. Two fcruples of calcined magnefia being mixed with half an ounce of perfectly colourlefs concentrated vitriolic acid, in a chocolate cup, the mixture grew very hot, but was but faintly ignited: in a fhallow veffel, to which the air had accefs on all parts, the earth was brifkly ignited, and the fmoak and vapors were more copious; but there was no flame. With the yellow vitriolic acid, the mixture became red-hot in a chocolate cup; and made in a fhallow veffel, it threw out fparkles of fire. With the black oil of vitriol, the mixture threw out fparks on all fides, at the inftant it was made: in a fhallow veffel, there arofe a brifk flame. As in order to produce a flame, it is neceffary for the vitriolic acid to be phlogifticated, it is evident that the light in thefe experiments arifes from the phlogifton: where the colourlefs acid was ufed, the phlogifton probably proceeded merely from this earth, which cannot but be fuppofed, after calcination at leaft, to contain fome fmall quantity of this principle. In none of the above inftances did the vapors fmell of fulphur; a phenomenon, which, if the phlogifton had not been deftroyed by the combuftion, would certainly have been obfervable. In every inftance the vapors were copious; as the ignition of the earth could not take place till the watery part of the acid was evaporated. In the laft, indeed, the heat was fo violent, and the union fo fudden, that the vapor itfelf was ignited, and flame was produced.

It deferves to be remarked, that M. *Weftrumb* candidly acknowledges that he finds a difficulty in accounting for thefe phenomena by the Crawfordian theory of fpecific heat, as the heat of the pale oil of vitriol being 0,758, and that of the dark-coloured but 0,429, the heat developed with the fame earth fhould be nearly twice as great in the former cafe as in the latter. The contrary, however, is the fact.

That calcined magnefia is not cauftic, may poffibly proceed from its ftill retaining, or elfe abforbing from the fire, a portion of phlogifton. [E]

fifting, according to my experiments, of about equal parts of fine filiceous earth and magnefia, which may be extracted from the former by means of concentrated vitriolic acid. From one ounce of it I obtained half an ounce and eight grains of magnefia, and half an ounce and twenty grains of filiceous earth. Similar conftituent parts, but in a different proportion, were found by *Rofe* in *talc*. From four drachms of talc, calcined with alkali, and elixated from it again, this Chemift, by means of concentrated vitrolic acid, extracted five fcruples of magnefia, and obtained in this operation feven fcruples of filiceous earth befides, that were left undiffolved. *Spanifh chalk* contains, according to my own analyfis of it, in one ounce three drachms and eight grains of magnefia, and four drachms and fifty-two grains of filiceous earth.

Among the *harder forts*, the *fteatites* confifts of the very fame particles as the fofter Spanifh chalk does. *Serpentine ftone* Marggraf has found to confift of equal parts of magnefia and of fine filiceous earth, mixed with a little earth of iron. The fame Chemift difcovered in one ounce of *lapis nephriticus* half an ounce and one fcruple of an infoluble filiceous earth, and two drachms and a half of ferruginous earth, and laftly, about two drachms of magnefia, which latter he extracted from it by means of vitriolic acid. The fame again, from two drachms of *Amianthus*, obtained one drachm and five grains of magnefia, and fifty-five grains of a filiceous earth, which was infoluble in acids. In an ounce of *afbeftus*, from *Zoeblitz*, I have found three drachms forty-four grains of filiceous earth, three drachms fifty-five grains of magnefia, and twenty-three grains of iron;—in an ounce of *tranfparent fhirl*, from Ehrenfriederfdorf, three drachms twenty-eight grains of filiceous earth, one drachm forty-fix grains of magnefia, two drachms forty-five grains of iron, and fome flight veftiges of fluor-acid;---in the fame weight of the *Grifon lapis ollaris*, three drachms four grains of filiceous earth, three drachms five grains of magnefia, one drachm fifteen grains of iron, thirty-two grains of earth of alum, two grains of calcareous earth, and about two grains of fluor-acid.

The *argillaceous earths* agree, it is true, with thofe of the preceding genus in this point, that like them they are foft and greafy to the touch, for which reafon they were alfo formerly ranked with them; but, in fact, each of thefe kinds have a different character, which, when they are fubmitted to chemical inveftigation, cannot be eafily miftaken. In the preceding it is magnefia, in thefe, the earth of alum, which by an intimate combination with fine filiceous earth, forms an invariable conftituent part of the argillaceous earths, with which in many forts may poffibly be united, (befides a portion of calcareous earth), calx of iron, and phlo-

gifton,

giſton. Excluſively of this, a portion of vitriolic acid is alſo commonly to be met with in the major part of argillaceous earths. The latter particles muſt be conſidered as merely accidental ſubſtances, and not neceſſarily appertaining to the nature of clay, the two former only being to be deemed ſuch; nevertheleſs much depends upon the proportion of them, as alſo in general upon their preſence or abſence. The pure argillaceous earths have been hitherto found to be abſolutely infuſible, even in the moſt intenſe degree of heat, and are only hardened in a red heat; the pure are diſtinguiſhed by a white colour, which they preſerve even after having been expoſed to a red heat; but if they contain calcareous earth, they will be in proportion to the quantity they contain, tough and eaſier of fuſion in a violent fire. This property of eaſy fuſion is alſo imparted to them by the calx of iron, which they contain, and which alſo is the cauſe that clays of this ſort acquire a red or brown colour by calcination. Mere phlogiſton without any metallic particles which tends to give a grey caſt to many clays, is in no caſe prejudicial to them, and is generally intirely expelled from them in the fire.

The *pure argillaceous*, or *alumitic earth*, juſt now mentioned, which is the earth that characterizes all ſorts of clay, has not as yet been met with native in its pure ſtate. We are obliged in every inſtance firſt to ſeparate it from other combinations. The moſt difficult way of any would be to extract it from the different kinds of argillaceous ſubſtances. But we obtain it in the moſt commodious manner, by employing for this purpoſe the materials previouſly elaborated by nature, by which this earth is already united with the vitriolic acid, and thus detached from argillaceous ſubſtances; in which ſtate it is found in alum. Accordingly, this earth may be moſt conveniently obtained by diſſolving one part of alum in eight parts of boiling water, and then filtering it and mixing it with a lixivium of potaſh, in like manner previouſly filtered, till upon adding this latter the alum ceaſes to become turbid; the whole mixture is then to be poured upon a canvas ſtrainer, ſtretched out upon a frame, in order to ſeparate the ſaline liquor from it. The thick magma remaining is, after this, put ſeveral times more into boiling water, that all its ſalts may be elixated. Then finally it is put again upon the ſtrainer and dried. With reſpect to even the pureſt earth of alum, however, it be obſerved that, notwithſtanding the niceſt elixation with boiling water, it will ſtill contain a portion of latent vitriolic acid *.

* The beſt method of detecting the vitriolic acid in it is deſcribed in the Chemical Journal, vol. IV. page 80. [A]

This proper component earth of clay has been found *tolerably pure* in ſeveral different places; and therefore in conſequence of more attention being given to it, no doubt might alſo be diſcovered in many more places. Under this is comprehended the *Lac lunæ*, found at Halle, in Saxony, which, according to *Schreber*, conſiſts for the greateſt part of pure earth of alum, united with a very minute portion of calcareous and ſiliceous earth, together with ſome traces of iron and phlogiſton†. The argillaceous earth of Urach, in the diſtrict of Wurtenburg, examined by Profeſſor *Gmelin*, conſiſted of $\frac{1}{4}$ of ſiliceous, and $\frac{3}{4}$ of alumitic, calcareous, and ferruginous earths‡. M. *Gerhard* alſo deſcribes a ſimilar argillaceous earth that was found in the principality of Munſterburg in Sileſia §.

The *principal conſtituent parts* of *common clay* are exhibited in *Marggraf*'s method, by mixing one part of clay with two of vitriolic acid, and diſtilling this mixture to dryneſs in a glaſs retort by a fierce fire. After the reſiduum has been well elixated with hot water, there will remain $\frac{3}{4}$ of fine *ſiliceous earth*, totally inſoluble in acids, but the remaining fourth which is the true earth of alum, is diſſolved in the concentrated vitriolic acid. From this latter earth is derived all the unctuoſity and ductility of the clay. Calcareous earth is diſcovered to be contained in different clays by their effervеſcing with acids; as indeed it may be likewiſe obtained from them by means of the nitrous or marine acid. Ferruginous earth is in all caſes known to be in them by their natural colour, but more ſo if they turn red, when calcined in the fire. But their ferruginous contents are ſtill better diſcovered by the magnet, after they have been expoſed to a ſtrong red heat together with a fat of ſome kind; or, by extracting the clay from them, by means of the marine acid, and then ſeparating the ferruginous particles from this latter. Sand, when contained in clay, is ſeparated from it by waſhing.

Of the *origin* of clay, nothing certain can be affirmed; except that *Beaumé's* hypotheſis is very far from being probable, who imagines that it is derived from gypſum, which was originally ſiliceous earth.

The pure *diffuſible* or *plaſtic clays* are eaſily ſoftened with water, and by this means are converted into a tough maſs; of which various veſſels may be formed, either by moulds or the lathe. They dry ſlowly, becauſe they retain water pertinaciouſly;

† *Naturforſcher*, or the Inveſtigator of Nature. No. 15, Halle, 1787. [A]

‡ Neueſte Entdeek. in der Chemie. vol. III. p. 3—40. [A]

§ Geſchichte des mineral reichs, or Hiſtory of the Mineral Kingdom, vol. II. page 290. [A]

whence

whence alſo this kind of ware commonly ſhrinks very much, and is ſubject to contract fiſſures; this happens moſt commonly with the pureſt and moſt unctuous kinds; burned in fire, they become hard and ſonorous. Excluſively of their compoſition as mentioned above, the different kinds may yet be diſcriminated from each other, by the uſes to which they are adapted.

Perfectly fixed *clays* are ſuch, as by a ſtrong fire may be calcined ſo hard, as to ſtrike fire with ſteel. They ſhould contain as little iron as poſſible. They are uſually indeed of a white colour, nevertheleſs there are ſome kinds of them which, from the admixture of various phlogiſtic particles, look grey or blackiſh; theſe latter are commonly, for this reaſon, more unctuous to the touch, but in calcination loſe all their colour and become white; however, when they contain a ſmall portion of ferruginous earth, they are generally of a reddiſh colour. With regard to ſand, this is ſometimes found in them in a greater and ſometimes in a leſs proportion. Of this we have inſtances in the fine *porcelain* and *pipe clays*, which, in the ſtrict ſenſe of the word, are *pure* clays.

The *Fayence* or *Delft-ware Clays* have in general, by nature, a grey or bluiſh caſt, which afterwards on their being burned changes to a yellowiſh hue; but in a fierce fire they may be melted down to a dark-green glaſs.

Common *Potters clay* is of a ſomewhat more compounded nature, and, in particular, contains a larger proportion of ferruginous earth. Its natural colour is commonly a yellowiſh brown or grey, which is a ſure indication of its ferruginous contents, which likewiſe ſhew themſelves ſtill plainer by this circumſtance, that this earth, for the moſt part, acquires a red colour, by burning, and melts down to a dark brown glaſs. The goodneſs of it depends, excluſively of the phlogiſton in its compoſition, entirely upon a moderate proportion of calcareous earth and ſand being at the ſame time contained in it. The common *brick clay* is a meagre kind of it, and conſiſts of clay, ferruginous earth, ſand, and a ſmall quantity of calcareous earth. The coarſeſt kind is *loam*, which, according to the difference of its compoſition, is of different colours and degrees of ductility. It commonly contains a greater portion of calcareous mixed with argillaceous earth; the ſmaller the quantity of the latter is, the worſe the loam will be found for uſe.

Good *Fullers-earth* ſhould be very ſoft and unctuous to the touch, eaſily ſoftened by water, and, like all kinds of clay, abſorb greaſe, and at the ſame time be totally free from ſand. A portion of calcareous earth will not make it unfit for uſe.

According to *Bergman*, the genuine English fullers-earth consists of clay, magnesia, and siliceous earth, mixed with a little earth of iron and marine acid.

Under the appellation of *Boles* occur various kinds of coloured clay, which in former times were used for medical purposes. Generally speaking they are nothing more than fine clays, which contain little or no sand, or siliceous earth; the greatest part of them are possessed of a large portion of ferruginous earth. Our ancestors used to mould them into particular forms, and marking them with certain stamps, use them as medicines, under the name of *terræ sigillatæ*, or *sealed earths*, which however our stomachs can now no longer digest.

When the ultimate particles of all these sorts of clay have attained in process of time to a more intimate state of combination, they lose the property of being softened by water; hence the *hemi-plastic kinds of clay*, which are sometimes to be met with, derive their origin. These are no longer reducible into their smallest molecules by water; but merely fall to pieces in it, with a slight noise, and no longer acquire from this fluid the ductility of the former species. Their induration may also proceed from another kind of earth being mixed with them.

If, in the same sorts, the induration is carried to a higher pitch, the *aplastic* or *indiffusible kinds of clay* are produced, which can now no longer be softened by water. These possess a greater degree of solidity, and, except in a very few instances, cannot be corraded without a knife, and otherwise occur in various forms. Of this, *Stone-marrow* (Stein-mark) the substance called *Wunder-erde**, and *red-chalk*, are instances, as has been shewn by *Marggraf*.

By a farther induration, finally, have been produced the more solid clays, or *argillaceous stones*. Among these I class the *Zeolite*, whose properties of yielding a frothy milk-white glass in the fire, and assuming a gelatinous appearance in acids, are, in fact, sure vestiges of earth of alum contained in its composition, which has been still more evidently shewn by *Meyer*, who found the *trasparent* sort to be composed of one half of siliceous—one third of alumitic---and one sixth of calcareous earth †. A hundred grains of *Sparry Zeolite* consisted of fifty-eight

* Or *Terra miraculosa Saxoniæ*. This substance, which, on account of its hardness, may rather be considered as a stone than an earth, is found at Planitz near Zwickau, in Saxony, in narrow veins that are diffused over the surface of the earth. It is variegated with beautiful colours, that represent all kinds of figures, such as towns, landscapes, rivers, &c. [A]

† Beschaft. der Berlin. Gesellsch. Naturf. Freunde, Vol. II, pag. 462—481. [A]

grains

grains and a half of alumitic---six grains and two-thirds of calcareous earth, and seventeen grains and a half of water*. According to *Bergman*, a zeolite from Adelfors, in one hundred parts contained eighty of siliceous---eleven of alumitic---and nine of calcareous earth. The common *writing* and *tile-slate*, as also the black *touch-stone* or *lapis lydius*, are undoubtedly to be considered as indurated clays.

Even *Jasper*, though some varieties of this species strike fire very briskly with steel, is nothing more than a ferrugino-argillaceous stone. This is not only confirmed by its whole appearance, in which it very much resembles a fine clay; but also by this circumstance, that *Ferber*, among other proofs, saw a Jasper in *Sardinia*, which on one side was still a crude soft bole; but this position is still farther proved by the chemical analysis of the stone itself, according to which, it consists of siliceous-alumitic-and martial earths. Add to this, that of such coloured bolar-earths, by calcination, an artificial jasper may be actually made, which will strike fire with steel.

Of the *Opal*, which, agreeably to the present state of our knowledge, is to be classed amongst the argillaceous stones, *Gerhard* affirms, that the acids did not act either upon the crude or the calcined stones: but that, after these had been calcined with alkali, one fifth of alumitic earth was extracted from them by means of vitriolic acid, and the rest was siliceous earth. M. *Meyer* by a similar operation separated from it one hundred and eighty-two parts of siliceous earth, thirty-six of alumitic earth, and one of iron. If in future no greater proportion of alumitic earth should be found in them, they may with greater propriety be classed among the argillaceous silices. *Gerhard*, in one drachm of the *Oculus Mundi*, asserts that he found forty grains of alumitic earth, ten grains of siliceous, and a small portion of an unctuous principle: and *Meyer*, exclusively of a little iron, discovered in it one hundred-and-one parts of alumitic earth, eighteen of siliceous, and five of murioecic or magnesia. This latter chemist is of opinion, that the opal is changed into oculus mundi, when by decaying in the air, it is deprived of part of its siliceous earth. *Gerhard* affirms, that the *Cats-eye* in like manner contains alumitic---and siliceous earths, only with this difference, that in one drachm weight, were found fifty-five grains of the former, and five grains of the latter. This passage however appears to be a mere oversight, or else an error of the

* Ibid. Vol. IV. No. 17.

press,

prefs, and to convey a meaning diametrically oppofite to that of the author; as immediately afterwards he fays, "hence it is probably, that it exceeds the two former fpecies in hardnefs, and alfo in fome meafure ftrikes fire with fteel." This would rather incline one to fuppofe, that the filiceous earth muft be more abundant in it than the alumitic.

*Gerhard* affirms, that *feldt-fpar* confifts of filiceous--alumitic--and calcareous earth, and alfo contains fome phlogifton; that it eafily fufes to a milk-white glafs, and occafions the fufion of almoft all other ftones and earths. In the experiments I have made on this mineral, I did not meet with any calcareous earth in it; but obtained from one ounce, five drachms thirteen grains of filiceous earth, two drachms thirty-fix grains of alumitic earth, eight grains of iron, and a little fluor acid. The conftituent parts of *Labrador-ftone* and *Moon-ftone,* both which are fpecies of feldt fpar, are not known as yet.

The conftituent parts of the *Bafaltes* of Stolpen are faid by M. *Meyer* of Stettin, to be in the following proportions: viz. that in one hundred parts were found fifty of filiceous,---fourteen $\frac{7}{12}$ of alumitic,---eight $\frac{4}{12}$ of calcareous earth, two $\frac{11}{12}$ of magnefia, and twenty-five of iron. According to Profeffor *Monch,* four drachms of Heffian bafaltes, confifted of two drachms thirty-fix grains of filiceous,---feventy-feven grains of alumitic,---two grains of calcareous earth, and five grains of iron. The origin of thefe fubftances is ftill very dubious. Some naturalifts have confidered them as cryftallized lavas, which during their fufion have acquired the form they are invefted with, becaufe they are often met with near and among other lavas, and alfo in the neighbourhood of volcanos. If fuch they be, they could not have originated from lavas in igneous fufion; becaufe no veftiges of a vitreous fufion are difcoverable in them. Perhaps they derive their origin from a ftream of humid and boiling-hot argillaceous lava. Others, on the contrary, think it equally probable that they were formed viâ humidâ.

In the laft analyfis I made of the black *bar-fhirl* of Schneeberg, I obtained from half an ounce, one drachm twenty-two grains of filiceous,---one drachm thirty-nine grains of alumitic earth, forty-nine grains of iron, and thirteen of manganefe. M. *Gerhard,* in the experiments he made upon the *Tourmalin,* found in this fubftance alumitic--filiceous--and calcareous earth, with fome phlogifton, which could not be feparated from the earthy parts by mere calcination.*

* Nouv. Mem. de l'Acad. R. des Sc. a. Berlin, pour l'An. 1777. [A]

The

The *Tyrolese Tourmalin* ſtrikes fire briſkly with ſteel, cuts glaſs as well as a diamond, and may be ground and poliſhed. Submitted to the blowpipe, it froths like borax, and at the ſame time emits a beautiful dazzling light, like phoſphorus, and melts very quickly to a white ſemi pellucid pearl. In the loweſt degree of heat it becomes electric, and in the heat of boiling water, its electric atmoſphere extends to the diſtance of an inch from its poles. It does not loſe the leaſt of its weight by torafaction: and by repeated ignition it loſes neither its tranſparency nor its electric property. When fuſed with the ſame quantity of borax, it becomes a browniſh-black tranſparent glaſs, which in cold aqua-fortis, changes to a pellucid jelly. It is ſcarcely acted on by concentrated vitriolic acid.

Neither can the argillaceous nature of *Toras* be denied, ſince *Carthuſer* has proved that it chiefly conſiſts of ſiliceous earth, with about a fourth of ferruginous earth of alum †. In the ſame manner *trap* conſiſts of mere indurated clay. In the *Rheniſh mill-ſtone*, Profeſſor *Succow* has diſcovered ſiliceous---alumitic---calcareous---and ferruginous earth; and in the *baker's oven-ſtone*, which is nearly related to it, ſiliceous---alumitic---and ferruginous earth, in which the former conſtitutes the greateſt part, and the earth of alum about a fourth only. According to *Achard*, 120 grains of *pumice-ſtone* conſiſts of ninety-nine grains of alumitic, fourteen of ſiliceous, five and a half of calcareous earth, and two of iron. But in the laſt experiments I made on this ſubſtance, I obtained from one ounce of it, five drachms twenty-ſeven grains of ſiliceous earth, one drachm fifty-ſeven grains of alumitic earth, twelve grains of iron and ſix of calcareous earth.

In the *micaceous Whetſtones*, or hones, the compoſition evidently conſiſts of ferruginous clay, quartz and mica. The compoſition of the *micas* themſelves too, which conſiſt of flexible, glittering, thin, more or leſs tranſparent, diviſible laminæ, is by chemical analyſis diſcovered to be argillaceous; of which the ſubſtances called *Cats-gold* and *Cats-ſilver* are inſtances. Under this head likewiſe is arranged *Muſcovy Glaſs*, (Vitrum Moſcoviticum ſive Ruthenicum) which *Roſe* has ſhewn to conſiſt of one third of alumitic and two thirds of ſiliceous earth.

To the *clays mixed with calcareous earths* appertains *argillaceous marle*, which conſiſts of about two thirds of clay and one third of calcareous earth. Nearly

† In his *Mineralogical Tracts*, Vol. II. pag. 19, & ſeq.

the ſame proportion is alſo found in *Stone marle*, (Stein mergel)* which on account of its hardneſs cannot be ſoftened again by being ſteeped in water.

The abovementioned argillaceous ſtones and earths may, conformably to their known natural properties, be uſed for a variety of purpoſes. The harder and more ſolid ſorts muſt be previouſly comminuted and filtered for theſe purpoſes, in the moſt advantageous manner. The purer kinds of them, on account of their infuſible nature, ſerve chiefly for ſuch veſſels and furnaces as are intended to reſiſt the fire. The hemi-plaſtic kinds, where they are found in abundance, are commonly applied merely to the melioration of arable lands that are barren. The uſe of the plaſtic kinds of clay, on the other hand, is of greater extent; ſince, by this property they make a tough paſte, which may be wrought up into a variety of forms. In the ſelection of theſe, attention muſt be paid to their known properties; and likewiſe, according to their different natures, they muſt be deprived of certain extraneous and prejudicial ſubſtances contained in them, and thus prepared for every purpoſe to which they may be applied. The purer refractory ſorts in particular may be uſed for the conſtruction of various furnaces, for the making tobacco-pipes, porcelain, and other ſimilar operations, in which they are ſubjected to the moſt intenſe heat.

Particularly the *melting furnace* for *glaſs*, *delft-ware*, *porcelain*, and other manufactories, in which the intenſe heat that is neceſſarily kept up in them would fuſe common clay, require to be lined internally with pure refractory clay. In like manner theſe ſorts of clay may alſo be uſed for the bricks themſelves, of which the furnaces are to be conſtructed, by mixing them accordingly as they are naturally poſſeſſed of a greater or leſs ductility, either with pure ſand or with clay previouſly well burned, and thus making them into bricks. The ſame refractory mixture is uſed likewiſe for the benches in the glaſs-houſes, upon which the pots containing materials ſubjected to fuſion, are placed.

*Crucibles*, *Dutes*, *Retorts*, *and Calcining capſules*, in like manner require pure refractory clay; but in general there muſt be added various other ſubſtances to

* According to our Author, both here and in his Introductory Chapter, (which on account of its appertaining entirely to Natural Hiſtory, we have omitted) ſtone-marrow and ſtone-marle, though they are confounded together by ſome late Engliſh writers, under the title of lithomarga, are different ſubſtances, the one being indurated marle, which conſtitutes the true lithomarga; and the other merely indurated clay. [E]

prevent

prevent the ſhrinking and cracking of the clay. In the *Heſſian* crucibles, which are ſtill preferable to all other kinds, pure quartzoze ſand, which is commonly ſomewhat coarſe, is mixed with the clay. Veſſels of this kind, nearly equal to theſe, are alſo made in Saxony. Alſo, inſtead of ſand, the fragments of pots, old crucibles, or veſſels of ſtone-ware groſly pounded, or well-baked refractory clay, reduced to a coarſe powder, may be added. Theſe materials undergo a ſemi-vitrification together, and form good crucibles. The beſt proportion of theſe ingredients depends upon the particular nature of the clay, accordingly as it poſſeſſes a greater or leſs binding power, or in proportion to its being more or leſs refractory. To one part of clay may be taken an equal quantity, or, from one-and-a-half, to twice the quantity of one or the other of the materials indicated above. The *Ypſen crucibles* are made of two parts of molybæna and one of a blue unctuous clay*. Inſtead of molybdæna, other micaceous ſubſtances alſo may be uſed. The latter are chiefly adapted to the fuſion of metals in large quanties; (though on being uſed for the firſt time, they are ſaid to change in ſome meaſure the ductility and colour of the noble metals) but are apt to be corroded by ſalts. The former, on the other hand, are more proper for the fuſion of ſalts and metallic glaſſes.

In order to the perfect attainment of the abovementioned object, the materials muſt be duely prepared. The clays ſhould be deprived as much as poſſible of the coarſer ſmall ſtones, and alſo the pyrites contained in them, and ſometimes left to effloreſce and decay in the air. In ſome caſes, after accurately conſidering the compoſition of them, clays that are in ſome reſpects defective, may ſerve, when mixed with others, for making equally durable veſſels. If the ſand be mixed with earthy particles, it muſt be freed from them, by waſhing in water. The burned clay, or the fragments of theſe argillaceous veſſels, as alſo the molybdæna, muſt be pounded fine and ſifted.

A circumſtantial detail of the proceſs in the preparation itſelf will be quite unneceſſary, as it will ſeldom happen that any Chemiſt will be under the neceſſity of making theſe veſſels himſelf, which he may buy cheaper, ready made. The manipulation chiefly conſiſts in ſoaking the clay in water, together with the

* The black-lead crucibles which are now in uſe in this country, are made at Chelſea, by Meſſrs. *Ruel* and *Hempel*, of plumbago mixed with clay, and ſeem to anſwer every purpoſe nearly, if not quite as well, as the Ypſen crucibles. [E]

pounded additions in order to ſoften it, and in making a homogeneous mixture of them, by treading and beating them up together. The large crucibles for glaſs furnaces are made up and moulded with the hand, and then dried; but the ſmaller ſorts are turned upon a wheel, and after exſiccation, properly baked either in an upright or horizontal reverberatory furnace. To the Heſſian crucibles, it is uſual to give a kind of glazing in the ſame manner as to other kinds of pottery, by throwing ſome common ſalt into the fire during the operation.

*Tobacco-pipes* require a very fine, tenacious and refractory clay, which is either naturally of a perfectly white colour, or if it have ſomewhat of a grey caſt, will neceſſarily burn white. Such colour conſequently muſt be derived from phlogiſton only, which may be deſtroyed by fire. A clay of this kind muſt abſolutely contain no calcareous or ferruginous earth, and muſt likewiſe be carefully deprived of any ſand it may contain, by waſhing. It ought to poſſeſs beſides the capital property of ſhrinking but little in the fire. In caſe it ſhould not be ductile enough, it may be meliorated, if required, by the admixture of another ſort. Finally, it is beaten, kneaded, ground, waſhed and ſifted, till it acquires the requiſite degree of fineneſs and ductility.

When after this preparation the clay has obtained a proper degree of ductility, it is rolled out in ſmall portions to the uſual length of a pipe, perforated with a wire, and put together, with the wire, into a braſs mould rubbed over with oil, to give it its external form, after which it is fixed in a vice, and the hollow part of the head formed with a ſtopper. The pipes thus brought into form, are cleared of the redundant clay that adheres to the ſeams, a rim or border is made round the head, they are then marked with an iron ſtamp upon the heel, and their ſurfaces ſmoothed and poliſhed. When they are well dried, they are put into boxes, and baked in a furnace. In the Dutch manufactories, theſe boxes conſiſt of conical pots made of clay, with conical lids, with a tube paſſing through the middle of them, by which the pipes are ſupported; or elſe they are long clay boxes, in which the pipes are laid horizontally, and ſtratified with fragments of pipes pounded ſmall.

Finally, the pipes, when baked, are covered with a glazing or varniſh, and afterwards rubbed with a cloth. This glazing conſiſts of a quarter of a pound of ſoap, two ounces of white wax, and one ounce of gum-arabic or tragacanth, which are all boiled together in five pints of water, for the ſpace of a few minutes.

In

In like manner the ſpecies of pottery called *ſtone-ware*, muſt be made of very fixed clay, which is either uſed by itſelf, or is mixed with other clay, or with fine ſand, or with burned and pulverized flints. This kind of pottery muſt be expoſed to the fire till the pieces run together; and their ſurfaces are abſolutely vitrified. This latter view is accompliſhed by throwing ſome common ſalt into the furnace, or ſtrewing it over the ware, or by rubbing it with brine before it is baked. Beſides this, it may alſo be actually glazed in the ſtrict ſenſe of the word; then painted, and baked over again. The *brown ſtone-ware* is made either of mere red bole, or of clay that becomes red by burning. This is alſo otherwiſe called *Jaſper porcelain*. Veſſels of this kind are made at Waldenburg, in the Diſtrict of Ertzgebirge; at Creuſſen, in Brandenburgh-Culmbach; at Burgdorf, in the Duchy of Lunenburg; as alſo in many villages in the neighbourhood of Hameln.

The beſt kind of *Stone-ware* is *the Engliſh*, which is of a white or yellowiſh colour, and is made near Worceſter, Derby, Burſlem, New Caſtle, and in many other parts of England. For the *white*, they mix pipe-clay waſhed, ſifted and diffuſed in water with calcined flints, or hard quartz pounded ſmall and ſifted through gauze. The mixture is deprived as faſt as poſſible of its ſuperfluous water, that the two earths may not be ſeparated from each other by the difference of their gravity. During the baking of the veſſels made of this earth, common ſalt is thrown into the fire. The *yellowiſh Stone-ware*, after it is baked, is covered with a brimſtone-coloured glazing, painted with various colours, and put into the furnace again, for the purpoſe of burning them.

The genuine ſemi-tranſparent *porcelain* which may juſtly be conſidered as the maſter-piece of the potters art, requires the pureſt and the moſt refractory earth, in order to be brought to the higheſt perfection of which it is capable. Its principal properties are: unfuſibility in the moſt violent furnace-fires: a hardneſs enabling it to ſtrike fire with ſteel: a ſmooth and poliſhed, but not vitreous fracture: a clear bell-ſound: a clean, ſmooth and ſhining furnace: a peculiar ſemi-tranſparency, which neither reſembles that of glaſs, nor that of opal, and a perfectly dazzling whiteneſs.

It is a remarkable circumſtance in the hiſtory of this beautiful production of art, that the Chineſe and Japaneſe invented it a long time ago, concerning which nothing can be determined with any certainty. In Europe, none was made before this century. *John Bottger*, a German from Schlaiz in Voigtland, was the firſt in Europe who invented the art of making porcelain. This man was appren-

apprentice to one *Zorn*, an apothecary at Berlin, where he met with an alchemiſt, who, probably in return for ſome good offices done to him by *Bottger*, promiſed to teach him the art of making gold. *Bottger* then, imagining himſelf to be in poſſeſſion of the ſecret of making gold, immediately concluded that his fortune was made, and ran away from Berlin into Saxony in the year 1700. Thither he was purſued, but found protection in that country; where they at length nevertheleſs urged him to give a ſpecimen of his pretended knowledge; which in fact, the poor fellow was not able to do, as he had been impoſed upon, and in truth, knew nothing of the matter. It happened however that once having mixed various earths together, in order to make ſtrong and durable crucibles, in the courſe of baking them, he accidentally diſcovered the art of making porcelain. Thus the intended tranſmutation took place, not in the metals indeed, but in his own perſon; and, as if he had been touched with a conjuror's wand, he was on a ſudden transformed from an alchemiſt into a potter. The firſt porcelain, which was manufactured at Dreſden, in the year 1706, was of a browniſh red colour, being made of a brown clay. The firſt white porcelain was made ſo early as in the year 1709, and in the year following the manufactory at Miſnia was eſtabliſhed *. The porcelain however did not arrive at its greateſt perfection till after *Bottger's* deceaſe.

In our days, where the knowledge of chemiſtry has made ſuch extenſive progreſs in the art of making porcelain, is no longer ſo great a ſecret as formerly.

The whole of this operation depends upon the compoſition in due proportion of abſolutely refractory ſubſtances with bodies of difficult fuſion. Of the former kind are pure ſiliceous earth and unfuſible clay: of the latter are various ſorts of plaſter-ſtone or gypſeous ſpars. The latter mixed with the former, produce the requiſite ſemi-vitrification.

The *ſiliceous earth* muſt be pure in the higheſt degree; white, and free from all metallic admixture, and alſo preſerve its colour in calcination. Pure quartz and white flints may ſerve for the purpoſe in thoſe countries in which no exceeding pure fine quartzoſe ſand is to be found native. The former muſt be ſoftened by calcining and quenching them, then pounded, ground and paſſed through a fine ſilk ſieve. Likewiſe, the clay uſed for this purpoſe, muſt contain no martial earth, and but very few phlogiſtic particles in general; and hence it muſt not yield a

* Vide *Beckmann's* Introduction to Technology. *Gottingen*, 1777. p. 220—225. [A]

coloured

coloured glaſs, when (as muſt be done) trial is made of it by vitrification. The clays generally uſed, and which poſſeſs theſe qualities, are of the diffuſible and plaſtic kind, white or barely of a light grey hue, which colour however they ought to loſe in burning. This earth ſerves partly to bind the different ingredients together; but partly alſo to promote a ſmall degree of fuſibility in the other ingredients, which otherwiſe are unfuſible. Previouſly to its being uſed, it muſt be deprived of the ſand it contains, by waſhing. The *gypſum* that is to be made uſe of muſt likewiſe be very pure, for which reaſon the cryſtallized ſort in particular is choſen: this is to be previouſly pounded, calcined in a copper caldron, properly ground to a very fine powder and ſifted. Inſtead of this the *fluor and ponderous-ſpars*, and alſo *fragments of broken china* may be added, in order to make, in a proper manner, a beginning of vitrification: theſe latter ſubſtances muſt be pounded in ſtone mortars, ground to a fine powder and ſifted.

This mixture of powdered flints and gypſum is called *Porcelaine fritt*, which is mixed as accurately as poſſible with the clay, (that muſt be previouſly waſhed and dried again) or elſe at all events with fragments of china reduced to powder. The requiſite proportion of all theſe materials cannot be determined univerſally, and for this reaſon cannot be the ſame in all manufactories. The principal point depends upon the nature of the clay, which is not the ſame every where, and ought therefore to be inveſtigated in each ſort by previous trials. Next to this, much depends alſo upon the conſtruction of the furnaces, and the degree of heat that can be produced in them, according to which more or leſs gypſum may be taken. Laſtly, when the ingredients are mixed together in the proper proportion, they are made into a paſte with rain water, and kept till the whole maſs has acquired a diſagreeable ſmell, a greeniſh colour, and the toughneſs of dough. This latter maceration of the porcelain maſs is deemed very neceſſary. In this operation a ſmell of rotten eggs ariſes, which ſeems to originate from the action of the vitriolic acid of the gypſum upon the phlogiſtic particles of the clay.

Of this tenacious paſte the uſual veſſels are then made by turning them upon a potter's lathe; but groupes, and other figures are caſt ſeparately in moulds, and afterwards joined on to the main piece, and curiouſly finiſhed with different kinds of wood or ivory inſtruments, with pencils and ſpunges. The turned ware, after being dried to a certain point, is preſſed in moulds, that each piece may have the ſame ſize and form, and then put upon the lathe again, and finiſhed with ſharp ſteel tools.

 All

All these pieces are afterwards put into cases or seggars likewise made of porcelain, and placed in the furnace, where they are moderatetly baked, but to such a point only that they still imbibe water, after which they are now first glazed.

For this glazing are taken quartz, fragments of china, and calcined crystals of gypsum, such as are used for the porcelain mass itself, and after being ground as fine as possible, they are diluted with a quantity of clean water. In this the half-baked porcelain vessels are hastily dipped one after the other, which instantly imbibe as much of it as is requisite, and as quickly dry, and then they are put upon the sand in the seggars formed of refractory baked and unbaked clay, and thoroughly baked till the glazing be well fused.

The *porcelain furnace*, which is commonly kept secret, must be constructed in such a manner as to produce the high degree of heat here required, for a sufficient time without aid of the bellows, and at the same time be capacious enough to contain a considerable quantity of ware together with the seggars at a time. The best furnaces are those, which are capable of having a fire perfectly equal throughout the whole of their cavity. In the German manufactories this furnace is said to be a parallellopipedon, of which the upper part, which is hollow, and closed in with a vault, contains the ware. The hearth where the fire is kept up, is on the outside, at the narrow end of the furnace opposite the chimney-place, which consequently is at the other narrow end. The flame passes through several apertures, conrived for that purpose, into the chamber, circulates in it, and issues by the chimney. The hearth and the chamber must be entirely constructed of refractory bricks, which for this reason are composed of the same materials as the porcelain itself. The grate likewise in which the fire is laid, must be made of these same kind of bricks; for a grate made of iron would melt, and give a tinge to the porcelain. Over the whole edifice is thrown a covering made of common bricks, of which also, all the lower part may be constructed.

For the fuel, well dried wood chopped small is used, which takes fire easily, and does not smoke.

When the ware is sufficiently baked, which is discovered by pieces of it that are taken out for the purpose, the furnace is cooled, and the sand with which the bottom of the seggars was covered, and which has adhered by fusion to the foot of the pieces of porcelain is ground off on a small grind-stone. After this, those pieces, which are not intened to be white, are painted with various enamelling colours, which are afterwards fused afresh in a separate furnace under muffles made of the porcelain-mass.

As far as we have been made acquainted with the materials, of which the Chinese make their porcelain, they use only two ingredients. The one in their language is called *Kaolin*, the other *Petuntse*. Kaolin is supposed to be an unfusible kind of clay, instead of which a talcy earth might serve equally well; and indeed, it is said that in France they actually use such for this purpose. Indeed, the Saxon porcelain-clay, which is said to be perfectly white, very brittle, meagre, mixed with a great many micaceous particles, and not to effervesce with acids, does not differ from it. The Petuntse is by some taken for a gypseous-spar, by others for a ponderous-spar, and by others for a species of feldt-spar. *Marggraf* says it is a kind of fluor-spar, known by the different appellations of *false emerald*, *false hyacinth*, *and false amethyst* *.

Common clay, according to the different states in which it is found, is employed for making coarse pottery, bricks and tiles, and for building in general.

Among the coarse potteries, *delft-ware* claims the first place. This kind of earthen ware, in former times called *Majolica*, is in fact, an imitation of porcelain, and constitutes the medium between this and common earthen ware. It is equal to porcelain in its external glazing, but in its interior fracture it looks rough like all other pottery. There are two sorts of this: the one is made of a fine white or yellowish clay, and covered with a milk-white glazing. The other is indeed also covered with an enamel, which however is not so white as that of the former. At the same time too the ware itself is also not so well manufactured.

For this manufacture are used very tenacious and unctuous sandy kinds of clay, which contain little or no iron at all, and are freed from the coarser particles of sand by washing, or the clay, after being macerated and diffused in water, is passed through a sieve. When the clay is sufficiently dried, it is trodden thoroughly with the feet, and by means of a lathe or moulds made into vessels and utensils of every kind. The piece having been moulded and turned again upon the lathe while half dry, is, after being perfectly dried, slightly baked, then covered with a milk-white glazing and once more baked, but thoroughly, in seggars. The enamel for this purpose consists of a hundred weight of minium, the same weight of sand, and forty of calx of tin; these will fuse together to a vitreous, milk-white, opaque mass, which is pounded to a coarse powder, and ground with water between two sand-stones to an extremely fine and smooth

* Vide his Chemical Treatise, vol. II. p. 45.

magma. These pieces may also be painted with fine colours, which are burned into them in a smaller kind of furnace. For the larger pieces the clay, by way of preventing it from cracking too much, is mixed with coarser sand, and the pieces when formed, are covered with the composition used for the finer kinds of delft-ware. When these pieces are to be covered with dark glazings, common potters clay also may be employed in order to save expence; which likewise is good enough for the cases or *seggars*, used for these pieces. Manganese gives to black glazings particularly a fine appearance.

For the *common pottery* may be employed almost all kinds of ordinary clay, which in the baking acquire a red or any other colour; provided only they be ductile enough, that vessels may be formed of them, and that they are capable of being baked hard. In these coarse kinds of clay this distinction should be attended to, that those, which are soon baked hard, with a moderate heat, and melt with a more violent fire, are the fittest for the cheaper and more useful kinds of vessels. The vessels made of this ware being somewhat porous, are moreover not so apt to fly in the fire; but on the other hand they require for this reason to be glazed on the inside, in order to prevent them from being penetrated by moisture. Again, there are other similar kinds of clay, the particles of which run together with a fierce fire, and by this shew a trifling incipient fusion, but do not fuse entirely: these, it must be owned, form hard and solid vessels, which are not so easily penetrated by the liquors as the former are, and also are more fit for the boiling of saline lixivia, but then they are more apt to crack in the fire. There are yet other kinds of clay, which become very hard in the fire, without the particles of them running together, and these form the most durable vessels. By the mixture of such different sorts of clay, many defects attendant on one particular sort may be removed, and a more useful composition obtained.

In the manufactory of the coarser pottery, every thing must be avoided that increases the expence, consequently the washing must be omitted here; and it is sufficient, after macerating it, barely to deprive the clay, by chopping, treading, and beating it, of its coarser impurities, and thus prepare it to be moulded. After this the vessels are moulded either with the hand or upon a lathe, or else pressed in moulds.

The ware thus brought into form is first dried in the air, and the coarser sort covered with some colour or other, and immediately glazed. The finer ware is more highly finished upon the lathe and polished; after which, it is for the

first

first time baked, glazed, and dried, then painted, and then baked again. The former kind is said to be *painted under the glazing*; the latter *painted upon the glazing*.

When the glazing is laid on before the baking, they use to wet with clay water that side only which is to be glazed, and to strew the dry pulverized glazing-matter upon it. But after the baking, the glazing is generally laid on wet, either by dipping the water in it, or by sprinkling the glazing upon it by means of a brush. The latter method has this advantage, that there is no occasion for glazing any other vessels but those that remain sound after the first baking; whereas, in the former mode, the glazing that turn out ill upon the vessels, is absolutely thrown away; besides, the waste of time and of fuel in the former method must likewise be brought into the account.

The glazing most commonly used is the more or less dark coloured sort prepared from lead. The most useful materials for the glazing itself as well as for the painting of it are: Litharge, red lead, lead ore, manganese, smalt, saffre, calx of tin, crocus martis, ochre of copper, calx of copper, antimony, clays of easy fusion, sand, glass, &c. All such ingredients are usually ground fine with a hand-mill, or levigated upon a stone. The baking of such ware is commonly performed alone in an oblong square furnace, furnished with a hearth, over which is placed a grate, upon which the ware is set.

For making *bricks* the coarser kinds of clay may be employed. Most kinds of bricks are made of common or impure clay. The brick earth that is most used, is of a more compound nature, and consists chiefly of argillaceous mixed with ferruginous earth, sand, and sometimes a little calcareous earth. The best sort is that which contains the greatest quantity of argillaceous earth; the less clay it contains the more meagre it will be found in the working and the coarser in the baking. What is wanting by nature to any particular kind of argillaceous earth may be supplied by art; so that any sort may be made fit for making good bricks by imparting to it the requisite qualities, either by an addition of sand, or by an admixture of other kinds of clay of opposite properties. With regard to the due proportion in its composition, it must be observed that when clay contains much of ferruginous earth, and but little sand and calcareous earth, it cannot sustain a violent fire in the baking, and easily fuses. But neither, if on the other hand these clays contain much of calcareous earth, is it then of any

any value, becaufe the bricks made of it will be foon attacked by air and moifture, and are very apt to moulder away. The *beft brick earth* muft contain much clay, a moderate quantity only of iron and fand, and ftill lefs calcareous earth or rather none at all. When the argillaceous earth naturally contains no fand, this muft be added to it, that by this means the clay may become meagre and folid, and the bricks not fufe fo eafily; whereas, on the contrary, from a redundancy of fand no folid bricks can be obtained. A large quantity of argillaceous and ferruginous earth will bear a pretty good portion of fand. The beft proportion muft be determined by repeated trials and experiments.

The clay being dug up out of the earth, is in the manufactories firft macerated with water in a pit made for that purpofe, and when it is fufficiently foftened, mixed with fand, if it be neceffary, or fome other kinds of clay, then trodden with the feet, and wrought up to a homogeneous pafte, which is then cut out into pieces, either for bricks or tiles, dried and baked.

*Tiles* in particular require a fomewhat more unctuous clay, and can bear a ftill lefs proportion of calcareous earth than bricks can. In an intenfe heat the calcareous earth caufes the tiles to fhrink, and if the calcination be not fo ftrong, it occafions them to be lefs durable, to imbibe water, and by degrees to be foftened by it. All tiles may be made very durable by a glazing upon their furface, either by the bare ftrength of the fire, or by throwing common falt into the kiln. If, during the calcination, feveral faggots of green alder wood are thrown into the kiln, the tiles acquire an iron grey colour from it.

For *bricks*, on the other hand, may be ufed a clay much more meagre, or mixed with agreater portion of fand, in proportion to their thicknefs and fize, but then they require alfo fo much the greater degree of heat. The *bricks or tiles ufed for flooring*, are generally made thinner, that they may be thoroughly burned and acquire a greater durability, fuitable to the ufe to which they are deftined. In Holland they have a particular kind called *Clinkers*; they are a yellowifh kind of bricks, made at Harlingen, in Friefland, of a white clay, which contains a little calcareous earth, and to which they add a fmall quantity of fand befides, in order to vitrify them. On account of their durability, they are ufed with particular advantage in buildings conftructed in or otherwife expofed to water.

In all kinds of bricks and tiles much depends in general on the degree of calcination. It is probable that a miftaken oeconomy that prevails with refpect to wood all over Germany, is the caufe that the greateft part of their bricks are not

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ſufficiently burned; whence alſo it may proceed that our modern buildings cannot be compared to thoſe which remain of our anceſtors. In many of the ancient Roman buildings yet extant, bricks occur that are evidently vitrified. Upon this circumſtance it is that the durability of all brick-work depends. Theſe maſſes of artificial ſtone would undoubtedly reſiſt air, water, and the ravages of time, if we gave them ſome degree of vitrification, a circumſtance, however, which is always neglected. It muſt moreover be remarked, with reſpect to the calcination itſelf, that an intenſe heat, not too long continued, is better than a weaker and longer continued one; becauſe by a weaker fire, the bricks are burned, leſs hard, and of courſe cannot be ſo durable. The larger the bricks are, and the more meagre the clay, the fiercer muſt be the fire that is applied to them.

*Common Loam* does not in fact eſſentially differ from brick-earth, excepting merely in the proportion of its conſtituent parts; ſince it contains leſs argillaceous and ferruginous earth, and alſo leſs phlogiſton, and on the contrary poſſeſſes more calcareous and gypſeous earth; for which reaſon it is meagre and brittle, and unfit for bricks.

The *Siliceous Earths* are diſtinguſhied from the preceding kinds by their greater degree of hardneſs, whence they ſtrike fire with ſteel, and hence are denominated *ſcintillant ſtones*. They are by ſome called by the very indeterminate appellation of *Vitreſcent*, or *Vitrifiable*; becauſe, with the addition of alkali they may be vitrified: whereas the other kinds of earths are likewiſe proper ſubjects for vitrification. Pure ſiliceous earth is not acted upon by any acid, except by fluor-acid alone, and cannot be fuſed by itſelf. But all the earths and ſtones of the ſiliceous kinds muſt be conſidered as being compounded; and by no means conſiſt entirely of ſiliceous earth, as has formerly been thought. Upon the greater or leſs degree of admixture in theſe earths, and upon the nature of the ſubſtances ſo mixed, depend their different degrees of hardneſs, and all the other properties of this genus, as tranſparency, colour, figure, and other differences.

Concerning the origin of theſe earths, nothing can as yet be determined with any certainty. It is barely probable, that all kinds of flints originate from argillaceous earth. This poſition ſeems to be plainly proved, not only by the different obſervations of ſome naturaliſts, as mentioned above, but alſo by the compoſition itſelf of theſe kinds of earth.

Among

Among the *mixed ſiliceous earths*, the following are chiefly to be claſſed. *Granite*, which generally conſiſts of an apparently homogeneous compoſition of ſmall fragments of feldt-ſpar, mica, and quartz. Thoſe maſſes in which one or other of theſe conſtituent parts is wanting, or in which ſhirl or ſteatites occurs, may be ſaid to be of the *granite kind*. Theſe conſtituent parts may for the moſt part be diſtinguiſhed by the eye; but at the ſame time they are joined with ſuch accuracy, that they appear as if they had been conglutinated together in a ſoft ſtate. The opinion of *Sauſſure*, that granites may poſſibly be the produce of cryſtallization, that their parts have been diſſolved in one and the ſame fluid, and finally concreted at the bottom of the liquor in cryſtals, which are ſometimes ſeparate and ſometimes mixed, in like manner as water ſaturated with different ſalts in the ſame veſſel uſes to ſhoot promiſcuouſly into irregular cryſtals, appears to me improbable, from a variety of obſervations. I am rather of opinion, that this lapideous ſubſtance was originally produced by the jumbling together of coarſe particles of quartz, feldt-ſpar, and ſhirl, waſhed off from their reſpective rocks, and intermixed with finer particles of mica, (which either was preſent from the very beginning, or aroſe afterwards from the compoſition of the feldt-ſpar) it was produced, I ſay, by all the particles being brought to cohere together by the interpoſition of water. Granite is reckoned one of the moſt ancient kinds of rock of the latter period of our globe. *Porphyry* is, like granite, a componud of different kinds of ſtone; with this difference however, that regular cryſtals of ſhirl or fluor-ſpar, or quartz, here are united together by an opaque and in general dark-coloured cement, conſiſting of the very ſame materials of which jaſper is formed. From theſe latter, the ſtone called *Pudding-ſtone*, is diſtinguiſhed inaſmuch as it conſiſts of ſpherical or oval fragments of different kinds of ſtone, chiefly flint, which being in like manner united together by means of a cement-like opaque ſubſtance, form one whole. *Gneuſs*, or *Gneis*, in ſome meaſure correſponds with the granite. It appears to be compoſed of quartz, feldt-ſpar and mica, ſhattered and rubbed into ſmall pieces, but differs from it by its ſlate-like foliated texture.

The *purer kinds of ſiliceous earth* poſſeſs a much greater degree of hardneſs and tranſparency, and therefore acquire alſo a finer ſplendor, when poliſhed. They ſtrike fire briſkly with ſteel, and by the moſt vehement fire can only be burned ſo

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as to become somewhat friable, but are never melted. To this class more particularly belongs quartz, two pieces of which being briskly rubbed against each other in the dark, emit a radiant light, and yield a peculiar smell. Fused with a fourth or third part of alkali or borax *, it forms a durable and solid glass. It is formed solid and massy in large veins, as well as crystallized in solitary clusters. There was formerly a difference made between this and the pebble; and naturalists were at great pains to determine this difference; which however was no where to be found. But it is now known with certainty, that there is in fact no other real difference between them, than a variation in their external form, and that the round field-or brook-pebbles, as they are called, are nothing more than pieces of quartz that have had their sharp angles rounded off by length of time. For my part, I take it to be, like most other stones, of a compound nature, because in the analysis I made of it, I extracted $\frac{13}{16}$ of pure siliceous earth, $\frac{2}{16}$ of alumitic, and $\frac{1}{16}$ of calcareous earth from it. In order to effect this analysis, pure quartz pulverized is to be fused, or else only calcined with four times its quantity of salt of tartar, the mass dissolved in distilled water, and precipitated with vitriolic acid, and a redundant portion of the same acid being added, set in digestion with it, then filtered, and all the saline matter perfectly elixated out of it with distilled water. Lastly, the whole of the liquor is to be mixed with the purest fixed alkali; and the precipitate farther examined. Common *Flint* (Silex communis *Cronst.* Pyromachus) which on account of its transparency is also called Horn-stone (though, strictly speaking, in mineralogy a different stone is meant by this appellation) probably consists of the same constituent parts, which in consequence of having undergone a previous solution, have entered into such a combination and state in which the whole has been indurated in a shapeless mass. *M. Voigt*, of Weimar, however has in his possession a specimen of crystallized flint from Johann-Georgen-stadt. Although these stones are often met with in beds of chalk, it nevertheless cannot be affirmed that they arose from it, and still less that this chalk originated from them. It is not improbable that they have arisen from an argillaceous earth, divided into very fine particles by solution in water, and introduced into chalk.

* Disquisitio Chem. de Silice. In novis Act. Acad. Nat. Curios. T. IV. in appendice. [A]

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The finer kinds of quartz or pebble, which are difcriminated from the reft by a greater degree of tranfparency and more pleafing colours, and on this account of grêater value, are called *Half-Gems* or *Semi-precious ftones*.

With refpect to *Chalcedony*, which belongs to this clafs, *Bergman* informs us that one brought from Ferroe, in one hundred parts, contained ninety-fix of filiceous and four of alumitic earth. On the other hand, *M. Bindheim* found two hundred and forty parts of *Icelandic Chalcedony*, the opaque parts of which did not ftrike fire with fteel, to confift of two hundred parts of filiceous, twenty of calcareous, two of alumitic earth, one of iron, and eleven parts compofed of fixed air, water, phlogifton and manganefe *. Of this, the *Cornelian* feems to be nothing more than a variety, the red colour of which may perhaps be derived from fome red martial earth attracted by it into its fubftance. So likewife the *onyx* is nothing elfe than a chalcedony compofed of different ftrata running in a parallel direction. Of the *agate* the very appearance plainly indicates, that it is moftly a mixture of chalcedony, flint, cornelian, jafper, quartz, and amethyft. Frequently too, its proper bafis is mere flint or chalcedony, interfperfed and fpotted with other earths that were introduced into it, when in its fluid ftate The *Chryfoprafe* of Kofemitz, according to *Achard*, did not fufe, though it loft its colour; in an ounce of it he found, as its conftituent parts, four hundred and fifty-fix grains of filiceous, eight grains of calcareous earth, fix of magnefia, three of calx of copper, two of ferruginous earth, and a little fluor acid.

Pure *Rock Cryftal*, with refpect to value, ranks among the femi-precious ftones, though in hardnefs, cryftallization and tranfparency, it comes very near the gems or precious ftones. Its matrix is quartz, and therefore thefe ftones are alfo called *Quartzofe Cryftals*. The obfervation, that in the place of their nativity, argillaceous earth is found in abundance, throws great light upon their origin and compofition, and agrees remarkably with all that has been mentioned before. This idea is ftill more corroborated by the chemical analyfis of it; fince Profeffor *Cartheufer* has found rock cryftal alfo to be compofed of filiceous, alumitic, and calcareous earth, though he does not feem inclined to admit the calcareous earth, which he actually obtained in his experiments, as a conftituent part of it; of which however there can be no doubt, as before him the exiftence of this earth

* Schriften der Berl. Gefell. Naturf. freunde, Vol. III. 1782. [A]

had been proved, *Westfield*, who extracted by it from this mineral by means of nitrous acid, and precipitated it in the form of selenite with vitriolic acid. According to *Achard*'s experiments, the *Bohemian Garnet* is brought into fusion by a violent fire. Thirty grains of it consisted of fourteen grains and a half of siliceous, nine of alumitic, three and a half of calcareous and three of ferruginous earth. Oriental *Hyacinth*, according to the experiments of the same Chemist, loses some of its colour in a continued red heat, and is perfectly fused in a welding heat. Thirty grains consisted of twelve grains and a half of alumitic, twelve of martial, six and a half of siliceous, and six of calcareous earth. *Bergman*, in one hundred parts of *Oriental Hyacinth*, reckons forty parts of alumitic, twenty-five of siliceous, twenty of calcareous earth, and thirteen of iron. Thirty grains of *Saxon Amethyst* are said to have consisted of eighteen grains of alumitic, nine of siliceous, three and a half of calcareous earth, and half a grain of iron.

With regard to the *precious Stones*, their purity, colour, and radiant splendour, together with their hardness, taken collectively, are the causes why in the general acceptation they have acquired a peculiar high value above the rest. The cause of their extreme splendour must be sought for in their transparency and foliated texture.

The *Saxon Topaz* from Schnekenstein, which was examined by M. *Marggraf*, was said to consist of alumitic and calcareous earth. *Bergman*, in one hundred parts of it reckons forty-six of alumitic,---thirty-nine of siliceous,--eight of calcareous earth, and six of iron. In the analysis I made of this gem, I separated from one ounce of it, four drachms eleven grains of siliceous---three drachms thirty-four grains of alumitic,---twelve grains of calcareous earth, and one and a half of iron. With respect to the *Chrysolite*, which is a variety of this, *Achard* reckons in thirty parts of it, nineteen and three quarters of alumitic,---four and a half of siliceous,---five and a quarter of calcareous earth, and one half part of iron. According to *Achard*, the *Oriental Emerald* only loses its transparency by being exposed to a violent red heat, without being fused by it. The constituent parts of thirty grains of it he found to be eighteen of alumitic,---six and a half of siliceous---two and a half of calcareous---and four grains of ferruginous earth. *Bergman*, in one hundred parts reckons sixty of alumitic---twenty-four of siliceous---eight of calcareous---and four of ferruginous earth. *Oriental Saphire*, according to *Achard*, was not perceptibly changed in a long-continued red

heat. Thirty grains of it contained feventeen grains and a half of alumitic---ten of filiceous---two of calcareous---and eight of ferruginous earth. *Bergman*, in one hundred parts of it found fifty-eight of alumitic---thirty-five of filiceous---five of calcareous earth---and two parts of iron. The *Oriental Ruby*, according to *Achard*, underwent no alteration from a long-continued red heat, and from thirty grains of it ten grains and a half of filiceous---eleven of alumitic---two and a half of calcareous---and three and a quarter of ferruginous earth were feparated as its conftituent parts. *Bergman*, on the other hand, in one hundred parts reckons forty of alumitic---thirty-nine of filiceous---nine of calcareous earth---and ten of iron. Agreeable to the account here given of the component parts of thefe ftones, among which the alumitic earth is found to have been prefent in fo confiderable a portion, the Garnet, Hyacinth, Amethyft, Topaz, Chryfolite, Emerald, Saphire and Ruby, ought rather to be referred to the argillaceous than to the Siliceous Genus. But before any thing can be decided with certainty upon this interefting fubject, I think it advifable to wait for further confirmation, founded upon the moft accurate and repeated experiments. Till then, I fhall leave them the place which they have hitherto occupied.

Thus much we know of the compofition of various gems. But of the component parts of the *Diamond*, the moft precious of them all, we as yet know nothing. The properties attributed to it by the lateft difcoveries, do not at all correfpond with the ideas which we had hitherto formed of this magnificent earthy body. Its fuperior hardnefs, in which it exceeds all other precious ftones, and its lately-difcovered property of totally evaporating in a violent fire, with a phofphoric light, appear to be fuch contradictory properties, as cannot be reconciled agreeable to our conceptions. But fo the fact is! The fault therefore perhaps may not lie in nature, but in our ideas. For why muft we directly combine the idea of abfolute fixity with that of a hard and heavy earthy body? Is it then impoffible for a folid earth, which otherwife of itfelf was abfolutely fixed, to be volatilized in combination with another body, by a certain degree of heat, efpecially with the affiftance of air? And may not this be precifely the cafe with the diamond? Certainly it may, as well as not. Until the diamond is, like other precious ftones, fubjected to repeated and more accurate chemical inveftigations, we muft remain in darknefs and uncertainty with refpect to this point. This defireable event however muft be poftponed, till the great difficulties which attend the execution of the experiments requifite for this purpofe fhall be removed by

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the patronage and ſupport of ſome ſovereign prince*. Till this period therefore arrives, all we can do is to conjecture, and compare together the ſimilar circumſtances. As ſoon as I was aware of the very remarkable property of the fluor acid, that it is capable of carrying off with itſelf the ſiliceous earth, in the form of vapor, the volatilization of the diamond immediately occurred to my mind. Suppoſe, for inſtance, in the diamond, the ſiliceous earth ſhould be combined with fluor acid? This ſuppoſition, it is true, is at preſent, perhaps, no more than the crude produce of a vivid imagination: but it may poſſibly in time attain to greater maturity, in conſequence of a more accurate inveſtigation of the ſubject. In the mean while I ſubmit it to be tried by the ordeal of the Public.

Reſpecting the *Chemical inveſtigation of the different kinds of earths and ſtones*, in order to explore their actual component parts, it is above all things neceſſary to be moſt intimately acquainted with the earths acknowledged as ſimple, and deſcribed at page 42—45; and to obtain a thorough knowledge of all the properties exhibited by them in combination with the different acids, ſince upon ſuch a knowledge, the whole of this inveſtigation muſt neceſſarily be founded.

In the amazingly diverſified compoſition of the great number of earthy bodies that are known, it is hardly poſſible to give directions that may apply univerſally, how they ought to be examined, and their conſtituent parts ſeparated. Undertakings of this kind appertain to the more arduous operations of Chemiſtry, and conſequently require a ſkilful operator. Hence, the beſt thing the Tyro can do,

* In a heat ſomewhat greater than that in which ſilver melts, the diamond is entirely volatilized and conſumed. It even produces a ſlight flame, and diminiſhes common air, juſt as phlogiſtic ſubſtances do, and leaves a ſoot; ſo that the extraordinary conjecture of Sir *Iſaac Newton*, of its being an inflammable ſubſtance coagulated, is fully confirmed.—*Bergman* kept diamond powder for three hours in a violent fire, in contact with the mineral alkali, without finding any viſible change in it: but having afterwards extracted the alkali by ſpirit of ſalt, the ſolution afforded, by the addition of vegetable alkali, a white earthy precipitate, ſoluble in all the acids; but with which, the vitriolic acid afforded neither alum, nor Epſom ſalt, nor ſelenite, nor ponderous ſpar, and conſequently it was neither argillaceous, magneſian, calcareous, ponderous nor ſiliceous earth, (ſince it is ſoluble in all the acids) but a new and diſtinct ſpecies, which with the vitriolic, forms a ſalt irregularly cryſtallizable, of a harſh acid taſte, and very ſoluble in water.—The phlogiſton is united to this earth in a very irregular manner: the vitriolic acid takes it up by digeſtion with diamond powder without becoming ſulphureous: but the inflammable matter may be ſeparated from the acid by evaporation: it then forms black combuſtible pellicles, which burn away almoſt entirely, leaving only a ſmall quantity of white earth. *Bergman* and *Delaval*, quoted by *Magellan*, in his Edition of *Cronſtedt's* Mineralogy. Vol. I. p. 127 and 132. [E]

will be to make himſelf previouſly moſt intimately acquainted with the deſcriptions of the analyſes performed upon different kinds of earths found in the writings of *Marggraf, Pott, Cartheuſer, Achard, Bergman, Scheele*, &c. and to regulate their proceedings by them. The principal part of the proceſs however will conſiſt in the following particulars:

Each *Earth* or *Stone* that is to be the object of inveſtigation, ſhould be choſen in the pureſt ſtate poſſible, and freed from every heterogeneous or foreign ſubſtance. After this the earths are to be triturated to a fine powder, and the ſtones, which on account of their hardneſs, cannot be directly pulverized, are to be rendered friable, by being made red-hot and quenched in water, in order that they may be capable of being likewiſe triturated to a fine powder. For this purpoſe, none but ſolid ſtone--or rather glaſs-mortars, muſt be uſed. Now upon the ſuppoſition, which is founded upon experience, that moſt of the earthy and lapideous bodies in nature, are compounded of different ſimple earths, generally recognized as ſuch, the artiſt muſt endeavour to ſeparate them from each other in ſuch a manner, by means of different acids, by extracting thoſe which are ſoluble from the ſiliceous earth, which alone is, of them all, inſoluble, or nearly ſo; and then again by ſeparating from each other, ſingly, out of this ſolution, the ſpecies of earths diſſolved in it.

The earthy or ſtony powder prepared with this view, may be attacked in two different ways: 1. A certain portion of it may be put into a retort, a quantity of ſtrong marine acid poured upon it ſufficient to cover it, and notice taken, if in this operation any efferveſcence enſues. If this be the caſe, it is in general a certain ſign of a ſolution of calcareous earth taking place; but if no efferveſcence be perceived, it muſt not therefore be directly inferred from hence, that no calcareous earth is preſent; ſince it may frequently be preſent, though not immediately acted upon, on account of its intimate combination with other earths. This however is only an obſervation made by the bye. At all events, the whole is to be diſtilled to perfect dryneſs. Upon this the reſiduum in the retort is to be expoſed to a low red heat, and elixated with diſtilled water*.

* The expoſure of the reſiduum to a red heat is particularly neceſſary, in caſe that among other ſoluble kinds of earth, calcareous earth is preſent, and is to be ſeparated from them. For, by urging it with a red heat, the marine acid is expelled both from the magneſia and the earth of alum, and, on the other hand, adheres to the calcareous earth only. In every other inſtance this expoſure to a red heat is not neceſſary. [A]

Now,

Now, ſhould there be any calcareous earth extracted and diſſolved by the marine acid, this, agreeable to its nature, will retain as much of the marine acid as it requires for its ſolution; while the other ſoluble earths, on the contrary, part with it in the fire. Conſequently by the addition of the diſtilled water, the calcareous earth united with the marine acid is here diſſolved, but may again be produced from it by means of a ſolution of fixed alkaline ſalt. It may not however be improper previouſly to try the earth, whether it be all calcareous or not. Farther, upon the reſiduum of the former part of the operation, at leaſt an equal quantity of concentrated vitriolic acid is to be poured, and abſtracted from it to total dryneſs. After which, upon this ſaline maſs alſo, diſtilled water is to be poured, and by this means all that is ſoluble ſeparated from it. This filtrated ſolution being ſuffered to evaporate by a very gentle heat, either Epſom ſalt, or earth of alum, or magneſia, each of them ſeparate, or all together, will be obtained by the enſuing cryſtallization in the earthy body. From which ſalts moreover, the abovementioned earths themſelves, by previous ſolution in diſtilled water, and with the aſſiſtance of a ſolution of alkaline ſalt, may be produced ad libitum. In this operation however, mere precipitation is not ſufficient, but the ſaline liquor alſo muſt be evaporated; ſince this may ſtill contain a conſiderable quantity of magneſia, if there was any in it at firſt, and which is not to be ſeparated from it but by evaporation. Now what remains undiſſolved after the laſt extraction with vitriolic acid, muſt be conſidered as an abſolutely inſoluble ſiliceous earth, of which one may be convinced by fuſing it with thrice its quantity of purified alkali, and diſſolving the maſs in water. If it be real ſiliceous earth, the whole of it will be diſſolved. If there had been metallic particles in the earthy body, they muſt have been ſeparated either by the firſt or ſecond ſolution, from which they may then be obtained by evaporation and ſubſequent expoſure to a red heat, and by a freſh ſolution following upon this, in the form of a brown earth, which will ſometimes be calx of iron, and at other times calx of copper. The *ſecond method* is, upon an earthy powder of this ſort directly in the beginning to pour twice its weight of oil of vitriol, to diſtill this from it to dryneſs, to expoſe it to a red heat, and to extract the whole of it again with diſtilled water. What remains after this will be a perfectly inſoluble ſiliceous earth, in caſe it ſtands the abovementioned trials; otherwiſe there may likewiſe be ſome terra ponderoſa in it. After this operation, upon gently evaporating the clear ſolution, a ſelenitic ſalt will

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be gradually ſeparated, if it be calcareous earth that has been extracted. The earth ot alum and magneſia will manifeſt themſelves partly beforehand by the taſte of the ſolution; and partly theſe earths will be more plainly diſcovered by the nature of the ſaline cryſtals that are obtained from them, after gentle evaporation. With regard to the abovementioned judgment to be formed of the extracted earths, by the taſte of the ſolutions, it will be very proper to prepare and keep in readineſs, ſolutions in all the mineral acids of each ſimple kind of earth in the pureſt ſtate poſſible, in order to compare them previouſly with thoſe that have been extracted.

In the inveſtigation of the earths, the following circumſtance alſo well deſerves to be remarked, viz. that in ſome ſorts, eſpecially in the more ſolid ſtones, the combination of the conſtituent parts with each other, is ſo ſtrong, that in many inſtances, the coheſion of the parts can be ſcarcely, if at all, deſtroyed. Now in order that one may not be induced too precipitately to infer from hence the further inſolubility of theſe earths, and thus fall into an error, the earthy body ought, before a final judgment is formed, for the ſake of attaining to a certainty upon the point, to be fuſed in an iron crucible with three or four times its weight of purified fixed alkali; and this ſalt again elixated out of it with boiling water. By this means the original intimate union of the different kinds of earths which in no other way could be overcome, is in many inſtances diſſolved; ſo that the extraction with acids may afterwards be accompliſhed in the moſt perfect manner. But even in theſe caſes, it will be neceſſary beſides to examine the alkali elixated from it, whether it has not perhaps extracted any of the earths itſelf, and to bring that alſo into the calculation with the other conſtituent parts; for fixed alkali has the property of diſſolving, by the aſſiſtance of fire, a conſiderable portion of ſiliceous and alumitic earths, and of carrying it over along with itſelf into the aqueous ſolution.

The *uſes to which the various kinds of earths and ſtones are applied in building*, are founded upon their nature, which muſt learned from their chemical properties. By an acquaintance with theſe, we learn the requiſite properties of the materials, the way to employ them to the beſt advantage, as alſo to cement them in the moſt durable manner, and preſerve them from untimely decay.

In the choice of the earths and ſtones, regard muſt be had to their requiſite properties, which muſt accord with the end propoſed. For a durable building, the ſtones muſt have the proper degree of ſolidity, reſiſt the damps, and conſe-

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quently not attract moiſture ſtrongly, or elſe they muſt be ſheltered from it, where they are to be expoſed to the open air. Now as the porous *Sand-ſtones* are very much inclined to imbibe water, remain damp for a long while, and laſtly, for this very reaſon are ſubject to decay, they are the leaſt durable. The purer ſort of *lime-ſtones* are more durable in all the different changes and variations of weather; but, on the other hand, the mixed kinds are very much diſpoſed to decay and crumble in the air. All calcareous ſtones, on account of their being calcined by fire, muſt be avoided in thoſe places where a fierce fire is required to be kept. For this uſe, *bricks* are moſtly fit, which, on this account, muſt be made of refractory clay, and burned as hard as ſtone. But when they are to be uſed in edifices conſtructed in the water, they muſt be ſtill more burned, and almoſt vitrified. Stones of the cheaper *ſiliceous kind* deſerve the preference above all others for building.

For the *cementing materials* of *ſtones*, lime, plaſter-ſtone, clay and loam are chiefly fit: the uſual methods of employing which are partly known to all maſons and bricklayers.

Of all theſe materials, *lime* binds the ſtrongeſt, when properly mixed with other bodies. In this mixture, every thing depends both on the good quality of the lime itſelf, as alſo upon the ingredients that are to be added to it. With regard to the requiſites for its good quality, all that is neceſſary has already been mentioned. In addition to this, it is neceſſary to obſerve, that it ought to be expoſed to the air as little as poſſible, that it may not, by attracting this fluid again, loſe its matter of fire, and at the ſame time the properties ariſing from it*. Since therefore quicklime cannot be kept long without loſing its good quality, and as nevertheleſs it is wanted from time to time, a proper ſtock of it ought to be ſlaked with a ſufficient quantity of water ſo as to form a thin paſte, when it muſt be put into deep pits, and well covered up with earth, and by this means be kept for conſtant uſe. Lime in itſelf however poſſeſſes no good binding quality; but in order that a good mortar may be obtained from it, it requires to be united with different other bodies by way of *additions*. For this purpoſe, gypſum, tarras, ſand, brickduſt, and even freſh quicklime ground to a fine powder, are employed.

* Or rather that it may not attract again from the air the aerial acid, which it had loſt by burning, the want of which conſtitutes it lime, and by the preſence of which it is reduced to the ſtate of chalk. [E]

When

When to three parts of a thin magma of flaked lime one of *powdered gypsum* is well mixed, a mortar will be obtained that will not crack, and is chiefly used in dry situations. No more however ought to be made of it at a time than can be used immediately.

By the addition of ground *Tarras* to flaked lime, a mortar is obtained, that after gradual exsiccation acquires an uncommon hardness, and which is chiefly used as a cement in such places, into which water is to be prevented from penetrating. Instead of which also hard baked clay, the small dust of pit-coal, lapis ollaris, &c. may be substituted.

The most usual addition to lime is *Sand.* The hardest quartzose-sand is fittest for this purpose, and the more so when it is not too fine, but in coarse grains and angular, such as is found in rivers and upon the sea-shore. It must however be freed, by washing, from all saline particles that may chance still to adhere to it, and also from all dust and dirt. With one part of strong lime flaked and in a fluid state, may be mixed two of sand, upon which must be poured besides a quantity of water sufficient to give it the proper consistence of mortar. In like manner, and in the same proportion, may coarse *brick-dust* likewise be applied.

In the same manner *quicklime* too may be used by way of particular addition to mortar that is ready-made. This is done after *Loriot's* invention, who asserts from his own experience, that from it a mortar is obtained which indurates very fast, does not crack, and becomes of such a stony-like hardness, that water cannot possibly soften it. For this purpose, one part of fine brick-dust, two parts of sifted river-sand, and so much of old lime that has been kept in pits, as is requisite to make these into mortar, are mixed together. Of this latter, half as much, by measure, will be necessary as of the two other ingredients collectively. Upon this the mixture must be made so liquid with water, as still to take up four parts more of quicklime reduced to a fine powder. The ingredients being accurately mixed together, the mortar must be used as soon as possible, because it indurates as fast as it is made. Hence always but a small quantity ought to be mixed at a time. Or, to the two parts of sand beforementioned, one part of brick-dust, and four of pulverised quicklime may be mixed together dry, and so much of it kept in sacks, as will be wanted to be used in a few days. Now when the flaked lime has been properly attenuated with water, the requisite quantity of this compound may be added to it at the instant that it is going to be used, and the mortar be immediately applied to the purpose for which it was intended. On account of the extraordinary quick induration of this mortar of *Loriot,* it

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may ſerve to prepare *artificial ſtones from ſand*, when poured into moulds and ſuffered to become hard in them*.

The other cementing material is *gypſum* or plaſter-ſtone, when it has been properly calcined or ground in the manner deſcribed before. It muſt be very well mixed with water, ſtirred about ſo as to form a thin mortar, and uſed immediately. In thoſe countries where it is not to be had in abundance and cheap, it is not uſed.

The third cementing material for ſtones is *clay*. This poſſeſſes many advantages above lime, which in various caſes render it neceſſary. Its property of being hardened by fire, in which lime, on the contrary, is rendered ſoft, make its uſe of unavoidable neceſſity in ſuch maſonry as muſt neceſſarily ſtand a fierce fire. On the other hand, it does not prove of equal duration with lime, when uſed for a wall which is to be expoſed to the open air, and muſt reſiſt the combined attacks of air and moiſture.

The fourth cementing material for maſonry is *loam*, which is nothing more than a meagre and coarſer kind of argillaceous earth; hence it does not bind ſo well as clay. It is however, like this, uſed for buildings and walls that ſtand in a dry ſituation, and alſo for fire-places, though in the latter caſes it does not become ſo hard as clay. To meagre loam, one third of clay may be added by way of improving its qualities.

The *preſervation* of brickwork and other ſpecies of maſonry would require leſs attention and trouble if good materials were always employed on it, and theſe again were prepared in the beſt manner. In the mean time all that art can contribute towards it, conſiſts in keeping out the damps as much as poſſible that otherwiſe penetrate into its ſubſtance. For this purpoſe as well as for the ſake of a better external appearance, the ſurface of the walls are covered with a gypſeo-calcareous plaſter, with or without the addition of ſand, which covering may alſo be painted, by way of an additional ornament, with ſuch colours as are not liable to be damaged, either by the nature of the lime or by the action of the ſun. The greateſt diſadvantage that attends maſon's work, is derived from the *ſalt-petre* which is generated in it, particularly in damp places. In theſe caſes an actual generation of ſaltpetre takes place, which in the beginning betrays itſelf by a hairy and evidently ſaline efflorеſcence, after which the

* A more circumſtantial account of this mortar is to be found in a work intitled *Neue Methode unaulſoſliche Malter und Kutte* zu macken. Vienna, 1775. [A]

mortar is by degrees raiſed up from the ſurface, and becomes brittle, till at length it actually falls off, and then the ſtones are themſelves corroded. In order to explain the cauſe of this nuiſance, an opinion formerly prevailed, that it was derived from the penetration of ſaline particles ab extra. But if this had been the cauſe of it, mortar made of unburned calcareous earth, and a wall cemented with common mortar at the upper part, ought to be likewiſe attacked by it, which however is not the caſe. In all probability the origin of this may be derived both from the mortar itſelf and from the damps penetrating into it, and this chiefly from the matter of fire contained in a latent ſtate in the lime, which in combination with the air impregnated with damp vapors, promotes the generation of the nitrous acid, which then attacks and corrodes the earthy parts of the mortar and of the bricks and ſtones. Now, conſidering the ſubject in this light, the beſt means of preſerving walls from this deſtructive enemy are, on the one hand, to remove the remaining uncombined matter of fire of the lime, and, on the other, to render the damps inactive upon the mortar. The former may be accompliſhed by the admixture of ſour milk or whey to the mortar. The other is effected by giving the walls, in the very firſt inſtance, the greateſt degree poſſible of hardneſs and ſolidity; the principles of which have been already mentioned before in this Treatiſe, and have been treated of more at large elſewhere *. But when this deſtructive foe has once begun its ravages in a wall, nothing remains to be done but to pick out as much as poſſible of the mortar, which is already become ſaline and corroſive, and to fill up the vacant ſpaces carefully with freſh mortar, of the kind mentioned before, that ſpeedily ſets or hardens; though I doubt whether, in the latter caſe, a permanent cure can be expected from it. To this ſubject alſo appertains a remark made by Mr. *Edward King* †, that ſand, by the intervention of diſſolved iron, becomes as hard as a rock; for which reaſon he adviſes an artificial compoſition to be made of common ſea-ſand with water impregnated with ruſty iron, and to cover with this the fronts of buildings, inſtead of gypſum or plaſter---and farther, frequently to ſprinkle the ſofter kind of ſtones uſed for building, with a ſimilar ferruginous water, in order to render them more ſolid.---This remark is confirmed by an obſervation made by Dr. *Fothergill*, who expoſed two ſtones of the

* Treatiſe on the origin of the ſalt-petre rot in *Actis Acad. Elect. Moguntinæ, ad ann.* 1776, p. 41. [A]

† Phil. Trans. 1779. p. 35.

ſame

ſame kind, in the ſame direction, on one and the ſame ſpot, to the open air, one of which he frequently wetted with water impregnated with the ruſt of iron; the other he left as he found it. In the ſpace of a few years he obſerved that the former had acquired a ſenſible degree of hardneſs and a metallic clang, but that the other remained in its natural ſtate.

*Coatings of Clay and Loam*, according to *Glaſer's* directions, may prove of ſignal ſervice in preventing the quick communication of fire from other buildings

☞ It ſhould have been obſerved at (page 361), with reſpect to the Engliſh Stone-ware, that according to Dr. *Watſon*, the preſent Biſhop of Llandaff, (See his Chemical Eſſays, Vol. II. page 259) the flint or white ſtone-ware, in Staffordſhire and other places, is made in the following manner: Tobacco-pipe clay from Dorſetſhire is beat much in water; by this proceſs the finer parts of the clay remain ſuſpended in the water, whilſt the coarſer ſand and other impurities fall to the bottom. The thick liquid conſiſting of water and the finer parts of the clay, is farther purified by paſſing it through hair and lawn ſieves of different degrees of fineneſs. After this, the liquid is mixed (in various proportions for various wares) with another liquor of, as nearly as may be, the ſame denſity, and conſiſting of flints calcined, ground and ſuſpended in water. The mixture is then dried in a kiln, and being afterwards beaten to a proper temper, it becomes fit for being formed at the wheel, into diſhes, plates, bowls, &c. When this ware is to be put into the furnace to be baked, the ſeveral pieces of it are placed in caſes made of clay, called *ſeggars*, which are piled one upon another, in the dome of the furnace; a fire is then lighted, and when the ware is brought to a proper temper, which happens in about forty-eight hours, it is glazed by common ſalt. The ſalt is thrown into the furnace (through holes in the upper part of it), by the heat of which it is inſtantly converted into a thick vapor, which circulating through the furnace, enters the ſeggar through holes made in its ſide, (the top being covered to prevent the ſalt from falling upon the ware) and attaching itſelf to the ſurface of the ware, it forms that vitreous coat upon the ſurface which is called its *glaze*.

This curious method of glazing earthen ware by the vapor of common ſalt, was introduced into England by two Dutchmen.

The *yellow* or *Queen's-ware* is made of the ſame materials as the flint-ware; but the proportion in which the materials are mixed is not the ſame, nor is the ware glazed in the ſame way. The flint-ware is generally made of four meaſures of liquid flint, and of eighteen of liquid clay; the yellow ware has a greater proportion of clay in it: in ſome manufactories they mix twenty and in others twenty-four meaſures of clay with four of flint. Theſe proportions, if eſtimated by the weight of the materials, would probably give for the flint-ware about three cwt. of clay to one cwt. of flint, and for the yellow-ware ſomewhat more clay. The proportion however for both ſorts of ware depends very much upon the nature of the clay, which is very variable even in the ſame pit. Hence a previous trial muſt be made of the quality of the clay, by burning a kiln of the ware. If there is too much flint mixed with the clay, the ware, when expoſed to

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already in flames: for which purpose also may be used penetrating liquors made of alum dissolved in water, or of a strong ley of wood-ashes, which are to be rubbed over the wood-work.

the air after burning, is apt to crack; and if there is too little, the ware will not receive the proper glaze from the circulation of the salt-vapor.

This glaze, even when it is most perfect, is in appearance less beautiful than the glaze on the yellow-ware.

The yellow glaze is made by mixing together in water, till it becomes as thick as cream, 112 *lb.* of white-lead, 24 *lb.* of ground flint, and 6 *lb.* of ground flint-glass. Some manufactories leave out the glass, and mix only 80 *lb.* of white-lead with 20 *lb.* of ground flint; and others, doubtless, observe different rules, of which it is very difficult to obtain an account.

The ware, before it is glazed, is baked in the fire; by this means it acquires the property of strongly imbibing moisture; it is therefore dipped in the liquid glaze, and suddenly taken out; the glaze is imbibed into its pores, and the ware presently becomes dry. It is then exposed a second time to the fire, by which means the glaze which it has imbibed, is melted, and a thin glassy coat is formed upon its surface: the colour of this coat is more or less yellow, according as a greater or less proportion of lead has been used. The lead is principally instrumental in producing the glaze; as well as in giving it the yellow colour; for lead, of all the substances hitherto known, has the greatest power of promoting the vitrification of the substances with which it is mixed. The flint serves to give a consistence to the lead, during the time of its vitrification, and to hinder it from becoming too fluid, and running down the sides of the ware, and thereby leaving them unglazed.

The yellowish colour which lead gives, when vitrified with flints, may be wholly changed, by very small additions of other mineral substances. Thus, to give one instance, the beautiful black glaze which is fixed on one sort of the ware, made at Nottingham, is composed of twenty-one parts, by weight, of white-lead, of five of powdered flints, and of three of manganese.

The coarse stone-ware made at Bristol, consists of tobacco-pipe-clay and sand, and is glazed by the vapor of salt, like Staffordshire flint-ware, but it is far inferior to it in beauty. [E]

SECTION.

# CHAP III.

## HYALURGY, or the CHEMISTRY GLASS.

UNDER the denomination of *Glaſs*, is underſtood a body more or leſs tranſparent, reſplendent, very hard, brittle, and fuſible in a ſtrong fire; which is artificially prepared by means of the moſt violent fire, and is not affected either by water, ſpirit of wine, oils, or by the major part of acids *. It has beſides the very remarkable property of becoming electric by friction.

Glaſs is, properly ſpeaking, an earth rendered tranſparent by fire; for the baſis of all the ſubſtances in general, of which glaſs is or may be manufactured, are *earths* and *ſalts*, though the latter, when in a pure ſtate, never fuſe to glaſs by themſelves. All earths are, in fact, fit for this purpoſe; but they are not all fit for it by themſelves; ſome of them are vitrifiable with great difficulty, others again not at all; but with certain additions they may all be reduced to glaſs. For this reaſon it is neceſſary to add to them various ſubſtances of eaſy fuſion, which are ſuitable to this intention, in order to promote their fuſibility. Theſe additions ſeem to exert a two-fold effect; 1ſt, becauſe being commonly more diſpoſed to fuſe of themſelves than the earths, they are able to bring refractory bodies into fuſion together with themſelves; 2dly, becauſe, on account of their greater degree of fuſibility, they act as ſolvents on the refractory body: but to produce this fuſion the moſt intenſe heat is requiſite; the matter of fire, which is here preſent in great abundance, muſt alſo have a great and eſſential ſhare in this effect. All theſe additional ſubſtances act here in combination with the matter of fire upon the bodies, which are either infuſible or of difficult fuſion, in the ſame manner, comparatively ſpeaking, as water rendered active by the nitrous acid, acts under the form of aqua fortis, upon a crude calcareous earth. Thus in vitrification,

* The acids of fluor and phoſphorus only are known to act upon glaſs. [A]

according

formably to the degrees of affinity eftablifhed by nature, a feparation in like manner takes place between the homogeneous particles of the refractory body, by the power of attraction of the other particles, and at the fame time a new mutual combination of all the different parts with each other. In the fame manner, therefore, as by the nitrous acid a grofs, palpable, and opaque calcareous earth is changed into a bright tranfparent folution, the grofs earth of flint is melted by the alkali and by the power of the fire converted into glafs. The pure matter of fire is confequently the proper, active, fluid folvent in vitrification, as, to return to our comparifon, it is upon the pure acid only, that the diffolving power of an aqueous acid menftruum depends. And farther, as an acid remains united with the diffolved body, it is alfo probable, that in like manner an effential part of the matter of fire remains intimately united with the glafs, and has a fhare in the tranfparency of it fimilar to that which water has in the tranfparency of cryftallized falts. Vitrification therefore confifts in the folution of various earthy bodies by fire.

Of the origin of glafs, nothing certain can be affirmed. Thus much however is known from hiftory, that glafs veffels were ufed long before the birth of Chrift. Probably mere accident gave the firft hint how to make it; perhaps this happened in the burning of lime or bricks

According to the different materials employed for making glafs, glaffes may be claffed into *Earthy*, *Saline and Metallic*.

*Earthy glaffes* are fuch as have been prepared folely from earths. It is true, all the fimple kinds of earth, except pure clay and flint, are vitrifiable. As thefe glaffes, on account of being too tough, cannot be conveniently managed, fome other particular kinds of earth are added to them in order to render them fomewhat more fufible. Earths fit for the vitrification of clay, are lime, gypfum, heavy and fluor fpar; flint is made vitrifiable by lime or gypfum, or by the abovementioned vitrifiable mixtures, and calcareous earth, by fluor fpar. In general all thefe kinds of glaffes are much more refractory than others, neither can they be formed fo well into veffels; they likewife poffefs a greater degree of hardnefs *.

* Concerning the ufe of Lava and Bafaltes for making glafs bottles, vid. Chemical Annals, Vol. I. p. 334; alfo the German Mercury, January 1785, p. 95. [A]

Of

Of salts alone no glass can be made; because, to produce all the properties of glass, earthy bodies, which alone possess that degree of hardness and insolubility that glass ought to have, are indispensably requisite; consequently there are no *wholly saline glasses.* Fused sedative salt, and the real pure salt of urine, are only glass-like bodies, which may be dissolved again in water, and at most contain only some earth of the crucible dissolved during the fusion. Glass made of the phosphoric acid, extracted from bones, is, it must be confessed, a real glass; it does not however consist purely of vitrified acid, but it has a considerable portion of earth for its basis, as I have proved by experiments; and this is the case with all saline glasses. By this appellation such glasses are to be understood, in which different earths have been vitrified by various kinds of salts, such as borax, fixed alkali, fusible salt of urine, and phosphoric acid.

Under the denomination of *Metallic glasses* are understood such as have been solely prepared of calces of metals by a sufficiently fierce fire. Of all the ignoble metals and semi-metals, the calces of antimony, bismuth and lead are the fittest for this purpose, and of these the first and last are the most generally employed. *Glass of antimony* may indeed be obtained from most of its calces prepared in different ways; but in preference to all of them, the calx, which is prepared from crude antimony or its regulus by calcination only, is chiefly used. This grey calx being treated in a crucible with a brisk fire without any other addition, fuses to a transparent glass, which is commonly of a brown colour, and more or less dark, accordingly as more or less phlogiston is contained in it. Sometimes the fusion proceeds rather slow, and this is generally the case when the calx has been calcined too much. But this inconvenience may be remedied by adding a little crude antimony to the mass, upon which the vitrification usually ensues very quickly. From this addition however the glass acquires somewhat a darker colour, than it has without the addition. Hence it is very evident, that there must be still some phlogiston in the glass, which follows also from the common observation, that every calx of antimony is vitrified with the greater difficulty, the more it has been deprived of its sulphureous and phlogistic parts. The case is the same with the calx of bismuth, which likewise fuses by itself very easily, and is converted into a yellow transparent glass, that passes through the crucible, and is called *Glass of Bismuth.* When lead suffers a semi-vitrification only, it is converted into litharge, which is generally obtained

obtained adventitiously and with a secondary view. But when litharge or minium is put upon a fierce fire, it produces a perfect and very transparent glass, called *glass of lead*, which, from a pure calx of lead, acquires a yellow colour, but by common litharge is tinged green. It attacks the crucibles into which it is put with astonishing violence, corrodes, and very readily runs through them; hence it is employed in those cases, in which different earths or metallic calxes are to be vitrified. But in order to prevent it from exerting its dissolving power upon the crucible with too great violence, the calces of lead are commonly mixed with a fourth or third part of calcined flint. With respect to the glass of antimony and lead, it is necessary to observe, that they are attacked by the weakest acids, and may be dissolved by them in small quantities. Attempts have been made to moderate its emetic power for internal use by the admixture of one-eighth part of melted wax to the powder, triturated as minutely as possible; it still however justly continues to be suspected by many physicians. The other metallic calces, which are not so easily fusible as these which have been just now instanced, may either be vitrified by the above-mentioned easily fusible, or some other vitreous additaments. It is a general rule to be observed, with regard to the vitrification of metal, that each metal must be previously deprived of its metallic splendor, which may be performed either by depriving it of its phlogiston, or by the combination of saline substances with it.

By such additions, very different metallic glasses may be obtained, which are discriminated from each other by their different colours; as each metal tinges glass of a particular colour. *Manganese* colours glass red; *cobalt* imparts to glass a blue colour; *arsenic* gives it no particular colour, but is in other respects a useful substance for vitrifying various earths and making the glass clear, and remains pretty strongly united with it and fixed by it. *Nickel* produces a green *regulus* of antimony and *bismuth* a yellow colour, *iron* sometimes a green, at others a blue, red, or black colour, *lead* a yellow, *tin* a milk-white, and sometimes a hyacinthine colour, *copper* sometimes a green, at others a blue or a brownish-red, *silver* a yellow, and *gold* a purple or violet colour. In the production and modification of these colours in the metallic glasses, much depends on, 1. the different preparation of the metals; 2, on the small portion of the metallic calx employed in proportion to the quantity of the vitreous mass; 3. on the degree of fire, and the time of its continuance; 4. on the quantity of phlogiston contained in it; 5. on the purity of each of the ingredients intended for the vitreous mix-

 ture;

ture; alſo, 6. on the difference of the ſalts that are employed. From hence, in theſe operations difficulties ariſe, which even the moſt ſkilful operator cannot always remove, and which often fruſtrate his intentions.

Moſt of the glaſſes in general uſe are of a compound nature; in fact, they conſiſt of a combination of different ſalts and earths effected by fire, and, according to the uſe to which they are applied, are diviſible in a general way into common glaſs, glazes, coloured glazes, and vitreous ſcoriæ or ſlags.

*Common glaſs*, as is well known, is immediately, on its firſt preparation, either formed into veſſels, or adapted to other uſes. In the manufacturing of glaſs, the firſt thing that occurs to be remarked, is the different earthy bodies, employed for this purpoſe, which are chiefly quartzoſe ſand, flint, gypſeous ſpar, chalk and the like. Some employ only one of theſe, others two or more ſorts together. The ſaline additions ought next to be conſidered, which conſiſt either of ſoda, common pot-aſh or only wood-aſhes, and amount to about the third part of the whole. Theſe ſubſtances being mixed together, to form the vitreous maſs, muſt be pounded tolerably fine, and then calcined in a calcining furnace of a particular conſtruction, for the ſpace of twenty-four hours, and repeatedly ſtirred, when the mixture is called a *Fritt*. By this calcination principally all air, moiſture, and perhaps ſome latent phlogiſton, prejudicial to the tranſparency of the glaſs, are expelled from the mixture. As ſoon as the calcination is ended, the fritt is put into the melting pots, which are in the glaſs-furnace, (properly ſo called) and is kept there in the moſt intenſe heat, till the maſs is ſufficiently fuſed, and has acquired the requiſite degree of tranſparency, of which the glaſs-manufacturer muſt aſſure himſelf, by ſamples taken out of the crucibles. After this the *ſandiver* or *glaſs-gall*, which conſiſts of the unvitrifiable ſalts, and ſwims at the top of the glaſs, that is of the conſiſtence of turpentine, is to be taken off; and now the glaſs is by means of the tube, ſheers, and tongs, moulded into different ſhapes, or elſe caſt for mirrors.

Every piece of glaſs ſo formed muſt, upon this be put into a heated furnace, which is called the *annealing furnace* that it may remain there for a certain ſpace of time, and cool gradually. For this purpoſe very large veſſels of refractory clay, filled with the glaſs pieces, ſtill hot, are put into the annealing furnace, and there kept, well covered up, till they are cold. This is done, becauſe, without ſuch precaution, all glaſs, by being ſuddenly cooled, acquires the bad quality of being apt to fly. Of this the well-known *philoſophical phials*, and the

the *Dutch tears*, or *Prince Ruperti drops* afford the moſt evident proof; the former of theſe fly into pieces, if the ſmalleſt piece of flint, or a pebble weighing a few grains only, be put into them. The cauſe of this phenomenon is placed, it is true, beyond the limits of our ſenſes; but if we conſider all that occurs in vitrification, the copious repletion of the fluid glaſs with the matter of fire, the toughneſs of its fuſion, the air which is diſengaged, even during the vitrification, from the materials fuſed together, as likewiſe the vapour which ariſes from the glaſs in this ſtate, to which may be added, the ſudden cooling of the ſurface of the veſſels after they are formed, it will appear highly probable, that a quantity of the elaſtic matter of fire, and perhaps with this a ſmall portion alſo of extremely rarefied air is incloſed in the interſtices of the glaſs. Agreeably to this theory, we may eaſily conceive alſo, that the matter of fire pent up in one of theſe unannealed glaſſes, and perhaps united with extremely rarefied air, may, when put into action by certain occaſional cauſes ab extra, produce the effects here alluded to, viz. the breaking of the glaſs into pieces. The remote and occaſional cauſe of this phenomenon, I take to be the matter which, in the friction of flints againſt each other, cauſes a particular ſmell, and in the dark exhibits a gleam of light. Since therefore, conformably to theſe obſervations, this fluid is ſet in motion whenever external friction is given to flints or ſiliceous bodies, the ſame muſt alſo proportionally take place upon the leaſt friction or percuſſion, and therefore I cannot but ſuppoſe, that the very ſame thing takes place, though in an imperceptible manner, when a piece of pebble is laid in one of theſe glaſſes. By its activity, excited by this means, a very ſubtle* influence is probably induced upon the interior ſurface of theſe glaſſes, by which the matter of fire incloſed in the glaſs is put into action, and occaſions it to fly into pieces; an effect which, as the action proceeds from the inſide outwards, is very much facilitated by the vaulted form of theſe glaſſes. On the contrary, when theſe glaſſes, after their formation, are transferred into another well-heated furnace, and kept there till by degrees they become cold; the too rapid contraction of their external ſurfaces is thereby prevented, and all the elaſtic and evaporable matter of fire, that is ſtill contained

* To ſo many of our readers this theory may poſſibly appear more ſubtle than true: but as the true theory ſeems to be a *deſideratum* in natural philoſophy, we did not think proper to exclude this. [E]

in their interſtices, has an opportunity to eſcape, and the glaſs is freed from the above-mentioned danger. What ſeems here to be occaſioned by the ethereo-igneous nature of the pebble, enſues in the *Dutch tears* in conſequence of the ſhocks which is given to their internal parts, on the breaking off of the leaſt part of their ſlender point; i. e. they inſtantly fly, and are reduced to powder with a pretty loud report. The experiment with the philoſophical phial was publiſhed in the year 1740, by *Paul Baptiſt Balbus*, an inhabitant of Bologna. But the properties of the Dutch tears were firſt made known in the year 1656. The place where theſe drops were invented is not yet determined, though ſome ſuppoſe it to be Leyden; according to others, Pruſſia, Sweden, and Germany, lay claim to this invention.

Common glaſs is diviſible in general into green and white. In the compoſition of the *green*, ſand only and wood-aſhes are uſed; and even clean elixated aſhes will ſerve the purpoſe. The colour of this glaſs is either brown or green, according to the quantity of phlogiſton, which happens to be preſent in the vitrified materials. But hardneſs and durability depend upon the greater proportion of ſand or ſiliceous earth in general: the leſs glaſs contains of alkaline ſalt or calcareous earth, the harder will it be, and the better will it reſiſt all acids. For the compoſition of the *white* glaſs, on the contrary, the pureſt materials poſſible ſhould be directly employed; ſuch as pure white ſand, or well calcined quartz, rock cryſtal, and flints, together with pot-aſh well purified and calcined, or other clean colourleſs bodies. Notwithſtanding this, the glaſs will generally be found ſtill of a greeniſh colour, of which however it may be perfectly deprived by a ſmall addition of calcined mangaueſe; but if too much of this be added, the glaſs will acquire an amethyſtine hue*.

If the glaſs be intended to be applied to different artificial purpoſes, in which a greater degree of eaſy fuſibility is requiſite, this is produced by a larger proportion

* If in the following paſſage of *Pliny*'s Natural Hiſtory, Lib. 36, Cap. 26, *Alteram naturam magnetis eſſe, attrahere in ſe liquorem vitri*, the word *liquorem*, which makes the paſſage abſolutely unintelligible, ſhould be conſidered as a ſlip of the pen, or an error of the preſs, and inſtead of it, be read *livorem*, the paſſage becomes comprehenſible, and may likewiſe ſerve for a proof, that even in this author's time the purification of glaſs by a metallico-mineral ſubſtance was known. But nothing elſe can be meant by this, than the ſubſtance now called mangaueſe, which in thoſe times was conſidered as being the female ſpecies of load-ſtone, becauſe it did not attract iron. Whence too, its name of *Magneſia*, terminating like nouns of the feminine gender, may poſſibly have originated. [A]

of alkali, arſenic, nitre, borax or calx of lead; but on the other hand it becomes ſofter by this means, and leſs capable of reſiſting acids. The calces of lead in particular are ſerviceable in making glaſs clearer and more tranſparent in conſequence of their diſſolving power; this glaſs alſo is ſuſceptible of a perfect poliſh, refracts the rays of light ſtronger, and on account of its exceſſive tranſparency may be uſed with advantage for making achromatic teleſcopes. It is known by the name of *flint glaſs*, and is prepared particularly in England for this purpoſe. Its real good qualities and the excellence of its nature depend more upon the high degree of perfection to which it is vitrified, than upon any determinate pro- of the ingredients.

*Artificial precious ſtones* are ſuppoſed to be imitations of the natural ones, and therefore we muſt endeavour to give them alſo the hardneſs and colour of theſe latter as far as art is able to do it. They ought to have withal the moſt perfect tranſparency, the moſt lively ſplendor, and not the leaſt bubble; for their baſis or fritt the fineſt and hardeſt materials ought to be choſen, to which is given the appellation of *paſte*. Of this kind is the mixture of two ounces of calcined and finely ſifted flints, one ounce of purified alkali, ſix drachms of borax, and two drachms of ceruſs. This mixture is to be fuſed in a very clean crucible, which can impart no colour to the glaſs, for eight or ten hours, and yields a glaſs of uncommon luſtre. But this end is attained ſtill better, when a mere earthy glaſs is choſen for the baſis, for the formation of which, flints, fine white clay, and magneſia alba, taken in equal parts, will ſerve; the addition alſo of a little fluor-ſpar is far from being prejudicial. An accurate chemical knowledge of the original compoſition of the natural precious ſtones, will give the beſt inſtructions with reſpect to this operation. Now, accordingly as this or that metallic calx is mixed with this fritt in different proportions, the coloured glaſs will, at leaſt in its colour, reſemble this or that coloured natural gem. It is generally ſufficient to every ounce of the above-mentioned paſte to add four grains of a metallic calx, prepared for the purpoſe, with which view the colouring property of the calx, as has been mentioned at page 384, may be taken into conſideration.

There is likewiſe a method invented by *Reaumur* of making the common green glaſs a milk-white *porcelain* of a particular kind, which this philoſopher has deſcribed in the Memoirs of the Royal Academy of Sciences for the year 1739, and upon the ſubject of which many experiments were

afterwards made by Dr. *Lewis*. The chief of the operation consists in this; a vessel of green glass is to be filled up to the top with a mixture of white sand and gypsum, and then set in a large crucible upon a quantity of the same mixture, with which the glass vessels must also be surrounded and covered over, and the whole pressed down rather hard. The crucible is then to be covered with a lid, the junctures well luted, and put into a potter's kiln, where it must remain during the whole time that the pottery is baking: after which the glass vessel will be found transformed into a milk-white porcelain. The glass, on fracture, appears fibrous, as if it were composed merely of silken threads laid by the side of each other: it has also quite lost the smooth and shining appearance of glass, is very hard, and emits sparks of fire when struck with steel, though not so briskly as real porcelain. *Lewis* observed that the above-mentioned materials have not exclusively this effect upon glass, but that powdered charcoal, soot, tobacco-pipe clay, and bone-ashes produce the same change. It farther appears from his experiments, that glasses which have been prepared with saline additions, are more especially fit for this purpose; and that those which contain the least salt are most easily burned to porcelain. The cause of this change probably depends, according to the observations made by different artists on the escape of a certain matter exhaling from the cemented glass. For in this treatment of glass, those particles of the sand which lie next to the surface of the glass are generally found to be somewhat baked together, whence it may reasonably be supposed, that the sand has attracted into its substance some of the saline matter of the glass; because sand is never found to cohere in this manner, by even the most intense degree of heat. It is probable therefore, that part of the alkaline salt, evaporating by the heat, penetrates into the materials which surround the vessel, and by the continued heat, so much of the alkali is expelled that the earthy basis of the glass only retains as much of it as is necessary, in order to make its particles cohere together. Now from hence proceeds the increase of its hardness and its opacity.

The vitrescent property of certain substances, among other uses, is also applied to *glazes*, by which are meant the shining glass-like coatings of earthen ware. This end is attained in two different ways: in the first; the surfaces of vessels of this kind, without applying any particular substance to them, are glazed while they stand in the baking furnace, with *saline vapour*, which is done by throwing some common salt into the fire. In the latter method a real and *substantial*

*coating*

*coating* is required for theſe pieces, which, in theſe caſes, is either of an *earthy* or a *metallic* nature.

Of the former kind, viz. the *earthy*, the glaze of the genuine porcelain may ſerve as an inſtance; this conſiſts of an eaſily vitrifying mixture of finely ground quartz, fragments of porcelain, and cryſtals of gypſum calcined, which are to be mixed with purewater. Into this compoſition are then expeditiouſly dipped the pieces of porcelain, which abſorb as much of it as is neceſſary, and when they are dry, are baked a ſecond time. But in order to add to the natural whiteneſs of the porcelain, ſome calx of tin is ſometimes added.

But as this glaze is not fuſible enough for delft-and potters-ware, which cannot bear ſuch a degree of heat; and, were it even made more fuſible by the addition of alkali, it would be then ſubject to be acted upon by acid menſtrua, and as it would be too tranſparent to cover the darker colour of the clay; and becauſe likewiſe the ſhrinking of the potters ware in the baking when they cool, does not correſpond with that of the earthy glaze, which would only become full of cracks by it: for theſe reaſons it is neceſſary to apply to this ſort of ware a ſtill more fuſible coloured metallic glaze, in the choice of which, at the ſame time, regard is to be had to its cheapneſs. With this view, for the ordinary potters ware is uſed the common yellow lead-glaze, made of quartz, and calx of lead, to which by the addition of bole, manganeſe, ſmalt, ochre, calx of iron, calx of copper, or antimony, may be communicated divers other colours. To the finer potteries a beautiful yellow colour may likewiſe be imparted, by a ſmall addition of ſolution of ſilver; or any other colour be given to glaſs of lead, by ſmoking it with damp hay. The *Tin-glaze* for the finer delft wares, which are only of a ſtraw colour, conſiſts of a glaſs-fritt compoſed of a hundred parts of calcined quartzoſe ſand, or flint, and ſixty-five parts of ſalt of ſoda, mixed with a tin calx of ſaturnine, which may be made of from four to five parts of lead, and ſix of tin; in which the tin produces the white colour, and the lead, the gloſs and the yellowiſh caſt. The proportion of the calx of tin cannot be conveniently determined for common uſe; but, on account of the different fatneſs of the clays, and the ſhrinking which is thence derived, ought to be aſcertained by previous trials in thoſe caſes where it is requiſite. The calx of tin may be added in equal parts to the above-mentioned glaſs-fritt.

The component parts of a glaze of this kind are to be mixed together, in the due proportion, and, at the time when the veſſels are baking, vitrified in the

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same furnace, then pounded, ground, and mixedup with water to a very thin consistence, in mills constructed for the purpose. Into this the crude-baked pieces are dipped, and with the glaze adhering to them transferred back into the furnace again, in order to fuse this latter. For the coarser kind of ware, potters generally strew upon the dried vessels, after wetting them a little, the bare powder of their ground lead-glaze.

There is another sort of tin-glaze called *Enamel*. By this is understood a very fusible, milk-white glaze, which is ground to a fine powder, and spread over various kinds of copper or golden imbossed work, in the form of a thick magma, and afterwards is brought to fusion under a muffle. As an instance of such a composition, the following mixture may serve: Ten parts of sand, two of purified alkali, ten or even less of lead, and three of tin, which two latter ingredients must be calcined together at the same time. If this enamel be wanted of any other colour than white, any other metallic calx ab libitum, may at the same time be added to this mixture. The Venetians are said to make enamels better than the people of other nations, for which reason also these articles are generally sold by them. The basis of the enamel, which, in general, must be opaque, may also be employed in imitating the opaque natural stones. In which operation, however, the proportion of ingredients ought to be somewhat different, with a view to produce a greater degree of hardness.

The *colouring Glasses* or vitreous colours, remain now to be mentioned. They are fixed colours, which are vitrifiable in the fire, and are necessary in painting and enamelling. Their base is a glass-fritt, and their colour proceeds from metallic calces, prepared by art. The latter however must be added in a greater proportion than is requisite for the natural precious stones*. The well-known *blue smalt* is a glass-colour of this kind, which in several countries is prepared in manufactories established for that purpose. It is compounded nearly in the following proportion: three parts of fine white sand, quartz or flints, two of

* A circumstantial introduction to this art is to be found in *Montamy's* Treatise on Colours for painting on porcelain, and in enamel. *Traité des Coleurs pour la peinture en email & sur la porcelain.* Paris, 1765, 8vo. Likewise in *Peter de Vieil's* Art of Painting upon Glass, and making different articles in Glass. Nuremberg, 1779 and 1780, Vol. I. II. III. large 4to. translated from the French. Some of these colours will also be described in a particular Section, where more of them are mentioned. [A]

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pot-aſh, and one of calcined cobalt-ore are mixed together, and fuſed to a dark-blue glaſs. This is then taken out with ſtout ladles of forged iron, and thrown into a large caſk, filled with water, that ſtands near at hand. By this ſudden refrigeration, the glaſs flies to pieces, and the ſubſequent comminution of it is much facilitated. After this it is pounded, ground, waſhed over, and diſtributed into different ſhades of colour, which are diſtinguiſhed by particular appellations. In the Saxon blue-manufactories many different ſorts of this commodity are manufactured; as 1. high colours: 2. colours: 3. aſh*: and 4. zaffre. Of the firſt kind there are the following ſorts: OH ordinary high; MH middling high; FH fine high; FFH fineſt high. Of the ſecond kind the following marks mean, OC ordinary colour; MC middle colour; FC fine colour; FFC ſtill finer colour; FFFC fineſt colour. Of the third kind the following marks indicate OE ordinary aſh; ME middle aſh; FE fine aſh; FFE ſtill finer aſh; FFFE fineſt aſh. Zaffre is ſaid to be nothing more than common calcined cobalt, which is commonly ſold under that name, mixed with three parts of quartzoſe ſand. The purer the cobalt, the darker the colour. Hence ſmalt has the fineſt colour, when the cobalt is diſſolved in nitrous acid and precipitated with fixed alkali, which however cannot be done in the great. As cobalt-ores alſo generally contain biſmuth, they ought to be previouſly freed from it by eliquation. To the glaſs-colours alſo may be referred the *Naples-yellow* (Giallolino), for which there are different receipts. Profeſſor *Beckmann* mentions the following from the Abbate *Giambattiſta Paſſeri*: One pound of antimony, one pound and a half of lead, one ounce of alum, and one ounce of common ſalt. On the contrary, M. *Fougeroux* has given from the ſame, the following formula: let twelve ounces of pure ceruſs, two ounces of diaphoretic antimony, half an ounce of calcined alum, and one ounce of pure ſal ammoniac be mixed together, and calcined by a moderate heat for the ſpace of three hours, in a covered crucible, till the crucible becomes barely red-hot; when the maſs will be found of a beautiful yellow colour. With a larger proportion of calx of antimony and ſal ammoniac, the yellow verges towards a gold colour.

Finally, under the denomination of *Scoriæ*, are underſtood vitreous maſſes, mixed together by fuſion, which are adventitiouſly obtained in the ſmelting works, without the production of them having been particularly intended. They are

* In the original, *Eſchel*. [E]

ſometimes of an earthy, and ſometimes both of an earthy and a metallic nature. In general, they ariſe from the earthy component parts of ores; ſometimes they alſo contain ſome metal or other, which, with a particular view, has been ſuffered to vitrify along with them. In the fuſion of ores in the great, ſome part of theſe vitreous ſcoriæ may be put back again into the furnace, by way of vitrifying the earthy parts that are contained in the freſh ores; on which occaſion the promotion of the eaſy fuſion of ſuch ſcoriæ muſt be the chief object of attention.

# CHAP. IV.

## METALLURGIC CHEMISTRY.

THE different ſpecies of metallic bodies conſtitute the particular object of this Chapter, in which I propoſe however to treat only of the inveſtigation of their ores, of the working of theſe in the great, and finally, the application of them to different uſes. I ſhall therefore confine myſelf ſolely to the art of *aſſaying*, to the proceſſes carried on at the *ſmelting-works*, and to the various kinds of *metallic preparations*. Whatever is neceſſary to be known with reſpect to the number of the metals, and their natural hiſtory, has already been mentioned, and is conſequently to be conſidered as a ſubject with which the reader is well acquainted.

*Metals* lie in the depths of the earth, united with various other bodies, and deprived of their ſpecific form; and in this ſtate bear the name of *ores*, the extraction of which from the earth, conſtitutes the buſineſs of the miner. But before the extraction of their metallic contents by fuſion, or the *ſmelting* of them, can be undertaken, it will be neceſſary to inquire what ſort of metal, and what quantity of it is to be found in a quintal of the ore; whether it be worth while to ſmelt it, or extract it by fuſion in the great; and in what manner the proceſs in the great is to be conducted, in conſequence of the knowledge thus acquired, ſo as to anſwer the purpoſe. The knowledge requiſite for this is called the *art of aſſaying*; and is in fact, the very ſame thing in little, that the ſubſequent operation of ſmelting is in the great. It is that on which the operation of ſmelting is founded, and, as it determines the metallic contents of the ores beforehand, it enables us to judge whether the ſubſequent ſmelting of the ores in the great has been properly executed, and the whole of the metal contained in them has been extracted without

without loſs. The aſſaying of ores may be performed either in the *dry*, or the *moiſt* way. The dry way is the moſt antient, and in many reſpects the moſt advantageous; and therefore ſtill continues to be the moſt uſed. For this reaſon it is chiefly inſiſted on here.

As in the practice of this art the operations are carried on in very ſmall portions, the operator has it in his power to uſe the moſt efficacious materials, as well as to have recourſe to the moſt expenſive inſtruments, and, in ſhort, to practiſe every method indiſcriminately, that he may judge conducive to his purpoſe. The ſmelting of ores, and in general the operations that occur in it, are for the moſt part performed in crucibles and dutes, with the blaſt of the bellows, or in teſts under a muffle, or on ſand-pots. The moſt uſual and efficacious *materials* for this purpoſe are: borax, tartar, nitre, ſal ammoniac, common ſalt, alkali, fuſible ſalt of urine, liver of ſulphur, lime, glaſs, glaſs of lead, charcoal powder, lamp-black, pitch, and the different fluxes, as they are called. Of theſe, the *crude flux* conſiſts merely of a mixture of two parts of tartar and one of nitre; and the *black flux* of the very ſame mixture, after it has been ſet on fire with a red-hot coal and detonated. The *white flux* is compoſed of the ſame ingredients mixed together in equal parts and detonated; inſtead of which purified pot-aſh may be taken, as it anſwers the ſame end; and laſtly, the *quick flux* or *powder of fuſion*, which conſiſts of three ounces of nitre, one of ſulphur, and one of fine ſaw-duſt, merely mixed together. In many inſtances too, *ſal alembroth* is uſed, conſiſting of equal parts of ſal ammoniac and corroſive ſublimate; likewiſe *lapis Pyrmeſon*, which conſiſts of equal parts of antimony, ſulphur and arſenic fuſed together; and alſo the maſs that remains after the detonation of one part of antimony and three parts of nitre, called *le fondant de Routrou*. Among the principal inſtruments, are to be reckoned, beſides ſeveral others, the moſt ſenſible balances that can be procured, and the ſmalleſt weights. Of the former, commonly three ſorts are uſed, as: 1. the *Aſſay* or *Grain balance*: 2. the *Ore balance*: 3. the *Lead balance*.

Of theſe, the *Aſſay balance* is the moſt ſenſible, the arms of which muſt be made of the fineſt ſteel, and of ſtrength barely ſufficient to carry two drachms without bending. It muſt always be incloſed in a box, provided at the top, and on every ſide, with panes of glaſs, that it may be kept from duſt; and, when uſed, not be diſturbed by the impulſe of the air. The *ore balance* is ſomewhat ſtronger, and may therefore carry from ſix to eight drachms. The *lead balance* is ſtill ſtouter, and is uſed for weighing from thirty to forty drachms.

 The

The *Aſſay weights* conſiſt of very diminutive weights, divided into very ſmall parts, conſiderably leſs indeed than any in common uſe. As in aſſaying, ſmall portions only are examined, and the aſſayer takes one drachm for a hundred weight of ore in the great, the aſſay-weight muſt be divided into the ſame number of parts, as the hundred weight is divided into in the great, in order that the contents of the ore obtained in this ſmall way, may in an inſtant be accurately determined, with reſpect to the hundred weight.

In the *Lotting of the ores*, the following manœuvres muſt be attended to: From a parcel of *picked clean ores*, which have not been ſtamped, an equal quantity, when the parcel has not been weighed or meaſured, is to be taken with a ſhovel from the middle, as well as from various other parts of it. But when theſe parcels have been weighed or meaſured, a ſmall portion muſt be taken from each hundred weight or meaſure of them, in the manner deſcribed above. This ore, taken from the parcel, is now to be pounded ſmall, well mixed together, and diſtributed into little round heaps. This heap is next to be divided through the middle into two equal parts, one of which parts is to be taken, and pounded ſtill ſmaller, again well mixed together, once more divided into equal parts, and one part thereof retained. This operation is called, *reducing the aſſay*; after this, theſe aſſays are once more to be finely pulverized in an iron mortar, well mixed, and laid by for uſe. In the ſame manner likewiſe the aſſays of roaſted ores are to be taken. From the *ſmall* or *offal of picked and bucked ores*, at the time that they are weighed, a ſpoonful is to be taken from each hundred weight, well mixed together, and reduced in the manner before deſcribed, then triturated in an iron mortar, and paſſed through a ſieve. The ſame proceſs ſhould alſo be followed in the main with the *ſtamp ſtuff*. In rich ore, containing native, mixed with the mineralized metal, the aſſays cannot be taken ſo accurately, becauſe the native metal is not diſtributed in the ſame proportion throughout the ore. The native metal, in ſuch a caſe, is rather to be picked out ſeparate, different pieces of it aſſayed, and the contents reckoned up together. The ſame mode of proceeding alſo is generally to be be adopted with reſpect to the vitreous ores. Of *pieces of eliquation*, a few pieces for aſſaying are thrown together into a little pit, whenever the hearth is emptied out; and when all is eliquated, melted down together. The aſſays of *teſted ſilver* are ſtruck out of the metal, proceeding from the middle to the edge; for about the edge they are generally the richeſt, and pooreſt

poorest near the middle; for which reason the assay must not be made either from the circumference or the middle only. In fine silver, as also alloyed silver, such as reguli and ingots, the assay is taken from the top and bottom.

With the ores thus reduced, the following preparatory process, viz. *The roasting*, is now undertaken, by which operation the sulphur or arsenic contained in them is expelled by fire. For this purpose, one or two assay quintals of ore must be taken and spread out upon a capsule, and put into the assaying furnace, under a muffle, where it is to remain till no more smoke is perceived to issue from it; at the same, time however, the fire must be moderated so as not to cause a fusion. The volatilization of the arsenic also may be still further promoted by the addition of some charcoal in powder. Ores of easy fusion, like the galenas, are only to be coarsely pounded. Antimonial and cobaltine ores are only to be roasted in tests over a charcoal fire, till they cease to smoke. Sometimes, also, the earthy parts may be previously separated by washing: but as the separation of the different metals cannot be effected under the same circumstances and by the same means, the whole will be best explained by a description of the particular investigation which is to be made of each of them.

As no mineralizing substance can be discovered in *pure manganese*, there is, properly speaking, no ore of manganese, excepting in those instances in which it is found mixed with other mineralized metals; it is at the farthest interspersed only amongst other stones; commonly it occurs most in these, in irregularly-shaped pieces, which may easily be separated from the stony part in this operation; and in this, properly speaking, there is no assaying. But if, nevertheless, a real *lapideous manganese* were required to be assayed, the simple process, indicated by *Bergman*, would probably best answer the purpose. According to that, a portion of this sort of manganese, steeped in oil, is to be put into a crucible well lined in the inside with charcoal in powder, and covered with the same at top; another inverted crucible put upon it, and the whole kept for the space of several hours in the most violent forge-fire *.

to

* M. *Sage* advises the powdered manganese to be mixed with $\frac{1}{10}$ of charcoal, and formed with water into a ball of the size of a filberd, which is to be put into a crucible, with an inch of powdered charcoal beneath, and another layer of an inch deep above it. *Mem. de l'Acad. des Sciences*, 1785.

An

To aſſay *an ore of cobalt* for the pure cobalt metal, the ore ſhould be firſt of all carefully roaſted, in order to expel the ſulphur and arſenic from it, and after this, one part of it muſt be fuſed in an open crucible, with two parts of the flux of tartar. Rich ores produce from fifty to ſixty per cent. *Beaumé* to two ounces of roaſted cobalt ore adds one ounce of alkali, half an ounce of pitch, and two ounces of decrepitated common ſalt, and fuſes the whole maſs by a violent fire, till the whole is brought to the moſt liquid fuſion.

In order to aſſay an ore for *arſenic*, the ore is to be beaten to pieces, and put into a matras, which is to be ſet in a ſand-pot. With the proper degree of heat, white arſenic ſublimes in this operation, and attaches itſelf to the upper part of the veſſel. Generally alſo, towards the end, when the fire is raiſed, a quantity of ſulphur will ſublime and generate realgar or red arſenic; upon which the fire muſt be immediately diſcontinued, and as ſoon as the veſſels are become cool, the arſenic may be collected and weighed. Arſenic is found in ores of cobalt, iron, tin, lead, copper and ſilver, but eſpecially in a peculiar whitiſh pyrites, which is called Miſpickel, water-pyrites or arſenical pyrites, and conſiſts of arſenic, ſulphur, iron, and an unmetallic earth *.

*Kupfer*

An anonymous writer, in No. 6 of the *Repoſitory*, a new periodical publication, recommends the mangan'ſe to be reduced to very fine powder, and made into a paſte with linſeed oil, which being evaporated in an iron ladle without ignition, more linſeed oil muſt be mixed with it, and evaporated three or four times ſucceſſively. The maſs is then to be wrapped up tight in paper in a globular form, and ſurrounded on all ſides with powdered charcaol, rammed very tight into a crucible. The whole muſt be kept two hours and a half in a white heat: when a regulus will be found weighing in general one-eighth of the calx employed. [E]

* In order to aſſay an ore for arſenic, the ore is to be bruiſed, and ſublimed in a glaſs bottle with a gentle heat, which muſt be made ſtronger by degrees, till all the arſenic is ſublimed. When the ſublimation is finiſhed, and the veſſel is cooled, the arſenic muſt be carefully collected together and weighed, with a view to diſcover its contents. But ſometimes one ſingle ſublimation is not quite ſufficient; for in many caſes the arſenic will ſmelt with the metal, with which it was combined, and thus by fuſing it, the metal will prevent its total volatilization. In this caſe, it is better to perform the firſt ſublimation in a very moderate heat, and afterwards bruiſe the remainder again, and expoſe it to a ſtronger heat.

If the ore, beſides the arſenic, ſhould contain a quantity of ſulphur, the ſublimate will be found to have a yellowiſh cruſt on its lower part, and in this caſe, if the cruſt ſhould be conſiderable, it is better to ſublime the whole by a ſomewhat ſtronger heat, ſo as to form ſanderach, or

real-

*Kupfer Nickel* is firſt to be roaſted, with a view to obtain its metal, the *nickel*. In the beginning, ſulphur, and then arſenic eſcapes, the latter of which occaſions the trifling effervefcence that is perceived in this mineral when brought to the proper heat. The greener the calx proves, during the roaſting, the more it abounds in the nickel, but the redder it is, the more iron it contains. The roaſted ore is fuſed in an open crucible with twice its quantity of white flux; when it uſually produces fifty per cent. of metal. This regulus, however, is not pure nickel, and commonly ſtill contains a quantity of arſenic, cobalt and iron; of the firſt it may be deprived, by a freſh calcination, with the addition of powdered charcoal, and of the ſecond by ſcorification; but it is with difficulty that it is entirely freed from the iron.

The aſſaying of an *ore of antimony* is effected in cloſe crucibles without any reducing additaments, and without the acceſs of air: for this purpoſe, two crucibles muſt be taken, the bottom of one of which enters one or two inches deep into the mouth of the other; the upper crucible muſt be perforated at the bottom in ſeveral places; it muſt then be filled with one or two pounds of the ore, (which however is only to be broken into pieces of the ſize of a haſel nut) and, with its mouth covered, ſet into the other crucible, ſo that a vacuum ſhall remain underneath it, and every juncture and aperture is to be luted with loam. The veſſel muſt now be placed upon a hearth, and ſurrounded with ſtones at the diſtance of half a foot. The intermediate ſpace is to be filled up with aſhes to ſuch a height that the undermoſt crucible may be covered with them; but upon the upper, charcoal is to be laid, and the whole made quite red-hot by the aſſiſtance of a pair of hand-bellows. The antimony being of very eaſy fuſion, ſeparates in this proceſs from the mineralizing ſubſtances, runs through the holes of the upper crucible into the undermoſt, and leaves the ſtony matter behind in the upper one. By the product of this operation that of the quintal or hundred weight may be eſtimated*.

realgar. But by far the greateſt part of arſenic is obtained adventitiouſly, in the roaſting of tin, cobalt, lead, copper, and ſilver ores; all which muſt be perfectly freed from the arſenic, if the metal be required in a perfect ſtate. Though the proper ore of arſenic and that which contains the greateſt quantity of this metal, is a whitiſh arſenical pyrites, the *Miſpickel*, or *Waſſerkies* of the Germans. [D]

* The ſame method is employed in ſmelting antimony in large quantities from its ores. [D]

The

The *Assays of Zinc* must likewise be performed in close vessels, because this semi-metal takes fire soon after it becomes red-hot. With this view four ounces of blend, or of native calamine, being pulverized, are mixed with one ounce of powdered charcoal, and put into a small earthen retort, coated. This is to be laid on a naked fire, furnished with a luted receiver, and gradually heated to incandescence, and kept at this degree of heat for some hours. The zinc, in this operation, passes over in its shining metallic form, and is deposited in the neck of the retort. Generally also, some light porous flowers of zinc are deposited in the receiver, which must likewise be comprised in the estimate *.

With regard to the *ores of Bismuth*, which commonly contain cobalt, the same process may be followed in assaying them as with ores of antimony. They require only to be smelted without any addition †.

In the *ores of mercury*, the mercury is united either with mere earthy substances or with sulphur. In the former case the assay may be made without any addition; but in the other case, to two parts of the ore it is best to add one of fine iron filings. In either of these cases a quantity, ad libitum, is put into a small iron, or coated earthen retort, which must be set upon an open fire, and furnished with a well luted receiver, into which some water has previously been poured. Upon this, by means of a fire gradually increased till the retort is quite red-hot, the mercury is expelled in its metallic state, which must be carefully swept up, and collected from every part where it may adhere ‡.

*Ores*

* That ores contain zinc, may be known by the flame they emit, when submitted to the blow-pipe, as well as by the white flakes which they exhibit at the same time, as also, by mixing them with powdered charcoal, and stratifying and calcining them with copper. [D]

† In order to assay an ore of bismuth, let the ore be pounded, and two parts of it be triturated with one part of calcined borax, and one of glass, reduced to a fine powder; then put this mixture into a crucible placed in powdered charcoal; let the crucible be exposed to a violent fire for about fifteen minutes; break the crucible, when cold, and taking out the button, weigh it accurately. The bismuth being of easy fusion, the same method of smelting it out of its ores may be adopted as in the smelting of antimony. [D]

‡ As quicksilver occurs most copiously in this latter state, viz. combined with sulphur, greater attention should be paid to use this kind of ore for the making of cinnabar than hitherto has been done, and part of this ore should be assayed for cinnabar, and another part of the quicksilver.

In

*Ores of platina* are not known as yet; therefore nothing can be said here of their docimastic treatment.

Of the *Assays of Iron*, it must be particularly observed, that all the calces of iron are not of the same nature, and that consequently they cannot be all treated in the same manner. M. *Ilsemann*'s * distinction between *ferruginous stones* and *iron ores*, with regard to the treatment of these substances, is very just; the former are those in which the iron is combined with earths only; but in the latter, on the other hand, the common mineralizing substances, sulphur and arsenic, must be present. The *ferruginous stones* may be distributed into *calcareous*, *argillaceous*, *quartzose*, *bituminous*, and *mixed*, according to the nature of their basis; and to the perfect fusibility of this earthy basis, respect must be had in choosing the requisite additaments, of which the following mixtures may serve for examples.

In the *Assays of ferruginous Stones*, roasting is with reason deemed unnecessary. Four quintals of *calcareous iron-stone* are to be mixed with, from $1\frac{1}{4}$ to $2\frac{1}{2}$ quintals of fluor-spar, (the more lime there is in the ferruginous stone the more fluor-spar) one of powdered charcoal, and four of decrepitated common salt.

To four quintals of *argillaceous* or *quartzose iron-stone* are added quick-lime and fluor-spar, of each $1\frac{1}{4}$ quintal, one quintal of powdered charcoal, and four quintals of decripitated common salt.

The *true Iron Ores* must be roasted. To four hundred weight of such roasted ore are to be added quick-lime and fluor-spar, of each two quintals, one hun-

In order to know whether the ore will answer for the purpose of making cinnabar, let some of the ore be pounded, and a certain quantity of it accurately weighed and put into a glass vessel, which, in the beginning of the operation, is to be exposed to a gentle heat, and to a stronger towards the end. By the quantity of cinnabar thus acquired, a judgment may be formed whether the ore will answer. Sometimes the cinnabar does not acquire that lively colour which is seen in that which is used in trade; in this case it must be refined by a second sublimation, and if it be still of too dark a colour, it may be made brighter by the addition of a quantity of mercury. But in case the ore will not answer for the preparation of cinnabar, and yet is combined with sulphur, two parts of the ore must be mixed with one of iron filings, when the quicksilver may be obtained from it by distillation. Sometimes the quicksilver will be found in its metallic form, loose in a stony matrix; in this case, it is procured by giving a few hard strokes upon the ore, but sometimes, though it is not combined, it is divided into so many particles, interspersed among the stony matter, that there are no other means of getting it, but by submitting the ore to distillation. [D]

* Gottingen Magazine of science and literature, 2d year, Numb. 6, 1782. Also Neueste Entdeck. in der Chemie. Vol. VI. page 31—46. [A]

dred and a half of powdered charceal, and four quintals of decrepitated common sal. In all these assays, the crucible, which contains the mixture, is to be covered with another inverted, and the junctures accurately luted. In this manner it is to be set on a forge before the nozzle of the bellows. When the crucible begins to be red-hot, the bellows are to be set to work, and the blast continued for about the space of three quarters of an hour. After some time has elapsed the crucible is to be taken from off the fire, and a few strokes given it, somewhat carefully, in order to promote the descent of the metallic grains; and lastly, when it is quite cool, the crucible is to be broken in two by a stroke on the bottom, and the contents examined whether there are still in the scoria any separate grains of iron, which being gathered together with the pure regulus, and weighed with the assay weights, the proportion of the pure iron to the whole is to be calculated *.

With

* The assays of iron ores are made, according to *Rinman*, (Forsok till Iarnets Historia. Stockholm, 1782.) *Roring*, (in *Rinman*'s Forsok. § VI. page 13.) and *Ilseman* (Neueste Entdeckungen in der Chemie, Vol. VI. p. 31) on the following principles: The ore must be roasted till the vapour ceases to arise. Two assay quintals of it are then to be triturated with one of fluor-spar, $\frac{3}{4}$ of a quintal of powdered charcoal, and four quintals of decrepitated sea salt. This mixture is to be put into a dute or crucible, lined on the inside with clay and powdered charcoal; a cover must now be luted upon the crucible, and the crucible itself exposed to a violent fire for an hour, and when it is cool, broken; when, if the operation has been well conducted, the iron will be found at the bottom of the crucible; to which must be added those metallic particles that may happen to adhere to the scoriæ, and which must be carefully collected for this purpose. If the scoriæ should still contain any metallic particles, they may be separated by wrapping the scoriæ in a paper, powdering them, and afterwards attracting the metallic particles from them with a magnet.

If the ore is a ferruginous or iron stone, properly so called, the same proportion of salt may be taken as in the former prescription, but only half that weight of fluor-spar and lime. The powdered charcoal may be added in the proportion indicated above.

If the ferruginous stone contains calcareous earth, there is no occasion to add any lime; the proportion of the ingredients may be as follows: two hundred quintals of ore, two hundred of decrepitated salt, one hundred of charcoal, and two hundred of fluor-spar: if more fluor-spar be taken, the flux will be too thin.

Iron ores, if they contain arsenic or sulphur, must previously be roasted, with a view to expel the sulphureous or arsenical particles, an operation that must sometimes be repeated. The roasting of the ores, if not detrimental, is however absolutely superfluous, when they contain the metal in the form of calx, mixed with some earth; this is the case with the marsh-or bog-ores.

Iron

With respect to all the assays of iron above mentioned, these general precepts beside remain to be inculcated: 1. That the metallic regulus ought to be pure, clear and

Iron ores, combined with quartz, or hard magnetic ores, in order to render them more fusible, and easier to be powdered, may be roasted till they acquire a blue steel colour. When the ores are sufficiently roasted, they must be cooled slowly, and afterwards reduced to a tolerably fine powder, with water. If the ore is a marshy ore, the sand or earth may be separated by washing. The melting of the ore is performed in two different methods. Either an attempt is made to make malleable iron of it, in one single operation, or to make crude iron of it at first, and afterwards to convert the crude into malleable iron. The first method is of course more simple, and may be applied to ores which yield at the first melting steel (crude steel) or very brittle untractable iron; but the quantity of iron obtained by this method is much smaller than by the other. In most cases then the latter method is preferable, viz. first to get the crude iron. This is performed either in *stick-ovens*, as they are called by the Germans, who used them formerly in Styria, or in high furnaces, which are chiefly in use at present, and the construction of which has been brought to the highest degree of perfection in England.

As frequently very different kinds of iron are obtained from different ores, the quality as well as the quantity of the iron must be attended to. [D]

M. *Ilsemann* has since (viz. in the Chemical Annals for 1787, Vol. II. page 505) given some improvements upon the method described above, of which the principal are these:

1. He has found that $\frac{1}{8}$ of charcoal is sufficient for smelting the ferruginous stones; and that a larger proportion than this is a hindrance to the operation.

2. A hearth must always be made in the dute, which may then be set at the distance of three fingers breadth only, from the nozzle of the bellows, and is besides not liable to be dissolved by the fluor-spar contained in the flux.

3. More flux is likewise added.

Feruginous minerals he divides into ferruginous stones and iron ores: and the former again into calcareous, argillaceous, siliceous, and mixed.

As ferruginous stones do not contain any sulphur, they need not be roasted: but the ores, for the contrary reasons, must.

For assaying ferruginous stones of the *argillaceous* and *siliceous* kind, to half a quintal of them let there be added of dry quick lime and fluor-spar, of each one quintal and a quarter; each of these must be reduced separately to a very fine powder, and the whole mixed with $\frac{1}{4}$ of a quintal of charcoal, likewise reduced to a fine powder, and put into a dute in which a hearth has been previously made of three parts of powdered charcoal, and one of tobacco-pipe clay. The hearth must be perfectly dry; a quarter of an ounce of decrepitated common salt is then to be added: the dute covered with a lid; and to be coated with composition made of clay sand, and chopped flax: this being done, it is to be set before the nozzle of the bellows, and the materials fused for an hour and a quarter, when the dute is to be removed from the forge, and as soon as it is cold, the regulus struck off and weighed. [E]



For

and without a cruſt, 2. that the ſcoria or ſlag muſt be ſmooth and well fuſed, compact and thoroughly vitrified. 3. That it is better to keep the aſſay a little longer in the fire than otherwiſe; and, 4. that it is proper to repeat the aſſay ſeveral times, and evenwith ſome other flux. If the products agree, it is a ſign of the accuracy of the proceſs; if not, more aſſays are to be made. In the reguli of iron there is, beſides, this difference obſervable; when the *cold* regulus is ſtruck with a hammer and breaks, the iron is called *cold-ſhort*; if it breaks, on being ſtruck, when it is red hot, it is called *red-ſhort*; but if it reſiſts the hammer, both in its cold and ignited ſtate, it is *good iron*.

*Lead ores*, when conſidered with regard to their fuſion, are diſtinguiſhed into three different ſorts; 1. into *lead ores of eaſy fuſion*, or *pure ores*; amongſt which muſt be reckoned the pure galenas, as alſo the green and white lead ores; 2. *Refractory* or *waſh-ores*, which are mixed with many kinds of ſtone; 3. into *ferruginous* and *pyritous* lead ores, in which the lead is mixed with ſulphur and copper, or rather with iron.

*Lead ores of eaſy fuſion* are at firſt to be gently roaſted, in doing which, however, the fuſion of them muſt be guarded againſt. To the roaſted portion remaining out of one quintal of unroaſted ore, are required two quintals of black flux, half a quintal of iron filings, and the whole to be mixed together, put into a wind-furnace, in a crucible covered with ſalt, and kept there for the ſpace of about an hour, in a fire ſlow at firſt, and afterwards raiſed by degrees.

*Refractory lead ores* or *waſh ores*, muſt firſt be beaten to a fine powder and waſhed, and then made into *ſtamp-ſtuff*. Now, an obſervation being made of the quantity of the ore produced by the ſtamp-ſtuff, it is aſſayed, and half, or a quarter of the roaſted ſtamp-ſtuff which remained out of ſixteen quintals of ore, is to be mixed with two quintals of black flux, borax and iron filings, of each one quintal, and ſet upon the forge, in a crucible covered with ſalt, to be fuſed.

For aſſaying *calcareous iron ſtones*, a quarter of an ounce of the calcareous ſtone, by the Germans called *ſteel ſtone*, half a quintal of fluor-ſpar, a quarter of a drachm of charcoal, each reduced ſeparately to a fine powder, are to be mixed together, and treated as directed above.

For aſſaying *iron ores*, the ore muſt be broken into pieces, as ſmall as peas, and half or quarter of an ounce of it roaſted, at firſt gently, but afterwards, with a briſk fire, two hours longer. The pieces are then to be pounded as fine as ſand, and roaſted again for the ſpace of two hours, with a ſtill fiercer fire, in order to expel the ſulphur entirely. The reſt of the proceſs is the ſame as for the ferruginous ſtones of the argillaceous kind. [E]

The *ferruginous* and *pyritous lead ores* muſt be roaſted in a fiercer and longer continued fire. To one quintal of them are to be added four quintals of black flux, and one of borax; the whole is to be mixed, and placed before the nozzle of a bellows, in a crucible covered with ſalt, and fuſed with a long-continued and violent fire. When theſe ores contain a great quantity of ſtony matter, they ought alſo previouſly to be reduced to ſtamp-ſtuff, and the weight of the black flux increaſed to ſix or eight parts. This latter quantity is neceſſary for this reaſon, that the ferruginous earth in the pyrites may be reduced, and that by this iron afterwards the ſulphur contained likewiſe in the pyrites may be ſcorified and ſeparated. In which operation therefore the latent ferruginous earth produces the ſame effect as was produced in the preceding aſſays of lead by the addition of the iron filings*.

The *tin ores*, in the aſſays to be made of them, are to be diſtinguiſhed into tin ores of *eaſy* and of *difficult* fuſion. Of the former kind are the real tin grains and zwitter; to the latter belong the ferruginous ſpecies of zwitter, and other minerals containing tin. Again, the tin ores of eaſy fuſion are either quite *pure*, or more or leſs *mixed* with mineralizing ſubſtances.

*The pure tin ores of eaſy fuſion*, or tin grains, muſt be roaſted in capſules, which at the commencement of the operation be covered with others, ſo that no part of the materials may be thrown out and loſt. Afterwards the cover may be taken off, and the roaſting of the ore continued, till there is no longer any ſmell of arſenic to be perceived. Now what is left behind in this operation, out of a quintal of crude ore, is to be mixed with two quintals of tartar, one of pot-aſh, and half a quintal of reſin. In the mean time an empty crucible, with another crucible to cover it, muſt be ſtanding on the forge, ready at hand, and red-hot. After this the upper crucible is to be taken off, and the lower filled with about a third part of the mixture; when the flame which ariſes has ſubſided, a ſecond, and finally, the third and laſt part is to be put into it. The uppermoſt crucible is then put on again, and a fierce fire made for the ſpace of a quarter of an hour, after which the upper crucible is taken off, and the materials

* Lead ores that contain ſulphur muſt be roaſted in a very gentle heat, till no more ſulphureous vapor ariſe; they may then be ſmelted with black flux; or, if it be not ſufficiently certain that all the ſulphur is expelled, it may be ſmelted with twice its quantity of black flux, a fourth part of iron filings, and a quantity equal to its own weight of borax; or, inſtead of this, of ſandiver. [D]

examined

examined whether they are well fufed, and boil without effervefcence. If this be found to be the cafe, the crucible is taken out of the fire, broken in pieces, when cool, and the metallic regulus weighed.

The *tin ores of eafy fufion, mixed* with ftony matter, muft be previoufly reduced to ftamp ftuff. Afterwards two quintals of it are to be roafted, and one-half of the roafted ftamp-ftuff mixed with black flux and borax, of each one quintal, and half a quintal of refin, and the procefs carried on in the manner defcribed before.

In affays of tin, fcarcely any addition upon the whole is requifite, than juft fuch as will prevent the reduced tin from burning to wafte, and to promote its fufion. Hence in this operation, befides black flux, either potafh or borax, is for the moft part ufed, which promote the fufion, at the fame time that the powdered charcoal, refin or pitch preferves the metals from being calcined or burning to wafte.

The *copper ores* differ much in their nature. The major part of them contain fulphur, and part of them at the fame time iron, and this often in the quantity of from thirty to forty per cent. and, on the other hand, fcarcely from three to four pound of copper. Relatively to their fufion, they are diftributed into three different kinds: 1. into *matt* ores, by which are underftood fuch as contain little copper and much iron, and from which the copper cannot be obtained in any other way than by reducing them into matts; by which means part of the iron is deftroyed. Of this kind are the greenifh-yellow, pale-yellow, and liver-coloured copper ores: 2. into *foft*-ores, which contain more copper and yield it eafier. Such are in part the fallow-copper ores*, and the deep-yellow, and quite colourlefs, alfo the iron-grey copper ores: 3. into *pure* copper ores, which contain the moft copper, though they are feldom free from fulphur and iron. They often yield their copper without being roafted, as for inftance, the coeruleum & viride montanum.

The firft fort of *poor copper ore* is fmelted into matts, in the following manner: An ore of this kind muft not be roafted at all, but only ftamped fmall. To one quintal of it four quintals of glafs muft then be weighed out, or

* In the original it is *Stahl-erze*; this is defined, *Mine de cuivre folide* in *Jacobfon's Technologifches Worterbuch*, probably the fame as that indicated by *Cramer* (Art of Affaying) p. 145. paragr. 368. But it is more probable ftill, that by an error of the prefs, *Stahl-erze* is put here for *Fahl-erze*, a well-known ore of copper, defcribed under the name of *Pyrites cupri grifeus* by *Cronftedt*, fect. 198. (325, *Magellan's* Edition.) [E]

four

four quintals, or inſtead of it, two of borax will anſwer the ſame purpoſe. Theſe two ſubſtances are to be well mixed together, covered with ſalt, another crucible placed inverted upon them, and fuſed in a forge furnace, the longer the better. An aſſay of this kind for the moſt part ſhould be expoſed to the blaſt of the bellows for the ſpace of three quarters of an hour, and even longer. When all is ended, after the materials are become cool, a regulus is found at the bottom of the crucible, which externally is dark, but internally brittle. In this operation the ſtony-matter only is ſeparated, and the matt obtained conſiſts of ſulphur and the metals. In this operation the firſt ſtep only is made. If the *matt* is to be farther worked for *copper*, it muſt be very ſlightly roaſted, ſo that only the ſulphur may burn at the mouth of the muffle; it is then to be fuſed afreſh with the ſame quantity of borax, ſo as to form a matt, which is now richer in copper, but will weigh leſs on account of the ſulphur having been diſſipated. This matt is now to be completely roaſted, and fuſed with three times its quantity of black flux, and half its weight of glaſs, and looſely covered with a crucible, when the regulus will for the moſtpart be free from iron. With regard to this latter part of the proceſs, the matt may alſo be completely roaſted at firſt, and fuſed afreſh, ſo as to form a matt, with one-third of crude ore, (that is, one-third of the weight of the crude ore of which the matt is formed) and the ſame quantity of crude borax, as the roaſted matt and the crude ore weigh together. This is to be completely roaſted, and fuſed in the uſual manner; when a regulus will be obtained containing leſs iron, and called *black copper*. But as this alſo ſtill contains ſulphur, iron and lead, it muſt therefore be now for the firſt time aſſayed for *red copper*, in the following manner. Two cupels are taken; into one of theſe when it is well dried by being kept for ſome time in a red heat, is put one quintal of black copper with four of granulated lead; and upon the other, one quintal of granulated red copper with the ſame quantity of lead, as was added to the black copper. The fire muſt be made up rather briſk in the beginning, that the copper may be diſſolved by the lead, but afterwards diminiſhed, ſo that the lead may not fine too faſt, and at laſt increaſe again; that all the lead may be conſumed, and the aſſays *lighten* in full heat. As ſoon as this has lightened away, ſome powder of charcoal is to be thrown upon the buttons that remain behind, the cupels taken out, and the buttons weighed when cold.

Now, in order to find the real contents of the ore from these two buttons, the following particulars must be observed: 1. It is known by experience that ten pounds of pure lead in the operation of fining copper, destroy at least one pound of copper: consequently the button obtained from the quintal of red copper can at most weigh only sixty-six pounds, and forty-four pounds of copper must at least have been destroyed by four quintals of lead. 2. It is certain, that the lead consumes less copper in the black copper, because it is more inclined to destroy the ferruginous, arsenical and cobaltic part, still contained in this substance. If therfore it be admitted, for instance, that the buttons of red copper, obtained from the assay of the black copper weigh sixteen pounds, the estimate will be as follows:

| | |
|---|---|
| Red copper weighed out | lb. 110 |
| The pure button obtained from it | 66 |
| Amount of the loss | 44 |
| The button obtained from the black copper weights | 16 |
| Both together amount to | 60 |

which is the exact amount of the quantity of red copper contained in the black copper.

*Soft ores* are kept at first in a gentle heat, and at last in the most violent roasting fire, during some hours, in capsules rubbed over with red chalk. The redder the ore is after the roasting, the less copper and the more iron it contains; but when, on the contrary, it looks dark and blackish, it contains more copper. In the former case, the half of the two quintals of calcined ore must be weighed out, and the same quantity of glass, four times the quantity of black flux, of resin or wood-soot, and borax or glass-gall, of each half a quintal, are to be added to it; the whole is to be mixed together, put into a crucible, covered over with common salt, and fused either in a wind-furnace, or forge, with a somewhat less fire than is requisite for the matt. In the other instance, the half of two quintals of crude ore is to be weighed out after being roasted, and mixed with an equal quantity of glass, four times its quantity of black flux, and a quarter of a quintal of borax. The whole is to be mixed together, and a little resin or wood-soot added to it. This ore will not bear a violent fire; but is only to be suffered to remain somewhat above half an hour, till the flame becomes clear, and the ebullition ceases.

*Pure*

*Pure copper ores* that contain no ſulphur, need not be roaſted, though it will do them no harm to keep them for a ſhort time in a red heat; as it is not at all unlikely that they ſhould contain a trifling quantity of ſulphur or arſenic in a latent ſtate. But as theſe ores again are of two different kinds, and are either *pure* or *mixed with ſtony matter*, they ought alſo to be aſſayed in a ſomewhat different manner. Of the pure ore one quintal, without being roaſted, is to be mixed with three quintals of black flux, and one of glaſs, covered with ſalt, and fuſed in a forge-furnace, till the flame becomes clear, and the ebullition, which laſts about half an hour, ceaſes. But when the ore is mixed with ſtony matter, half a quintal of borax beſides is to be added to the former ingredients, and fuſed with a ſomewhat ſtronger fire.

The aſſaying of *ſilver ores* again requires a different management, as they are chiefly diviſible into three different ſorts; as, 1. into ores of *eaſy fuſion*, under which are compriſed native ſilver, the *vitreous*, and corneous ſilver ores, the red and white ſilver ores and ſome others; 2. into *waſh-ores*, which are mixed with ſtony matter, and muſt be ſeparated from it by waſhing; 3. into *refractory ores*, which are either mixed with refractory materials, or with other kinds of ores, as cobalt, pyrites or copper, in ſuch a manner, that they cannot be ſeparated from them by waſhing.

With reſpect to the *ſilver ores of eaſy fuſion*, there are three operations chiefly to be attended to; 1. roaſting; 2. precipitation by lead; 3. cupellation.

As to the *roaſting*, there are, it is true, ſome ſilver ores that may be aſſayed without roaſting, which are ſuffered to roaſt during the ſcorification by lead; it is however ſafer previouſly to roaſt the ore a little, particularly if it ſhould contain a ſmall quantity of ſulphur or arſenic.

The *precipitation by lead* is performed in the following manner: one quintal of ore is to be taken either before or after roaſting, and eight quintals of granulated lead added to it. Firſt, one half of the lead is to be put into the teſt or capſule *, and upon this the ore, which is afterwards to be covered with the remainder of the lead. Immediately upon this, the capſule is to be put into a well-heated aſſaying furnace; at firſt, at the mouth only, but at length quite

* We have given the name of *Capſules* to the kind of veſſels deſcribed at page 85. They are improperly confounded with *teſts*, by Engliſh writers; from which, as well as cupels, they differ in the materials of which they are made. In the German language they are called *Treibſcherben*. [E]

into it, and a red-hot coal is placed before the mouth of the furnace. Now when the lead begins to melt, and the ore swims upon its surface, the mouth of the furnace is to be opened, the coal removed, and the capsule drawn more forward, that the sulphur and arsenic may be the better dissipated and expelled from the ore. After this, the test or capsule is again put into the furnace, a red-hot coal once more placed before the mouth of the latter, which is then shut up, till the lead is seen quite bright and shining in the middle of the capsule, and the ore flowing round it at the sides. As soon as this is perceived, the furnace is to be opened, and the capsule drawn forward again, that it may stand for about the space of a quarter or half an hour in a moderate heat to fine. Afterwards, the heat is again increased as before, that the whole may enter into a smooth and thin fusion, and the whole matter stirred with a hook thoroughly heated, especially towards the sides of the capsule, so that the whole may be equally mixed with the matter in fusion. Now, as soon as it is observed, 1. that the matter adhering to the hook runs off quite thin; 2. that only a thin glassy pellicle is attached to the hook; 3. that the scoriæ towards the sides of the capsule are liquid and clear like oil; 4. that the thick smoke has subsided; 5. that a clear leaden vapour begins to appear; and, 6. that, to appearance, no more than about half the lead that was added remains in the capsule; the fire for the assay is then to be raised; in the mean time some of the cavities in the assay plate are to be rubbed over with chalk: after this, the capsule is to be taken out of the fire with the tongs, and the matter immediately poured into the cavities. This matter is called the *Work*.

Upon this the *Cupellation* must commence. During the precipitation of the ore by lead, two cupels must be set inverted quite in the back part of the furnace, that their bottoms may become thoroughly red-hot: this is called (abathmen, or) *breathing* the cupels. When the precipitation by lead is finished, the cupels, being set upright in the furnace, are to be left there in the proper degree of heat, and the mouth of the furnace is to be closed again with the little doors. The whole of the glass and scoriæ is then to be separated from the work, which is to be hammered round and put into a separate small brass pot; at the same time a quantity of granulated lead is weighed out, equal to that which has been used in the scorification, which lead is called the *weigh-lead* *, and is also put into a separate

* Germ. *Bleyschwere*. [E]

parate

parate braſs pot. Every thing being ordered in this manner, the work is to be put into one cupel, and the *weigh-lead* into the other, and the ſame degree of heat is given to both, till the aſſay begins to look bright and clear; the aſſay is then to be conducted a little more gently, but not ſo that it ſhall *fix*; of which the following are the moſt certain ſigns: 1. The appearance of a brown ring round the inſide the cupels; 2. the vapour of the lead riſing only a little above the brim of the cupel; 3. A bright circle, like oil, is at times perceived encompaſſing the work; 4. the appearance of ſeveral ſhining rays, at different intervals, round about the work. This degree of heat muſt be continued till the quantity is diminiſhed to about half; after this the fire muſt be gradually encreaſed, till the button *lightens*. When this has taken place, the cupel is left in the furnace, till the button is fixed, that it may not be divided into a number of ſmall buttons by being taken out too ſoon. As ſoon as the aſſay is become ſolid in the furnace, it is taken out, and the button immediately detached from the cupel by a ſtroke with the point of the cupel-tongs, before it adheres too faſt. The ſame method is to be purſued with what remains of the weight-lead in the other cupel. After this the amount of the latter muſt be ſubſtracted from that of the former, and the remainder only ſet down as the contents of the aſſayed quintal. The above-mentioned cupellation of the mere weigh-lead muſt be undertaken at the ſame time, on account that all lead, except that of *Willach*, contains a ſmall quantity of ſilver. By this means, the amount of the ſilver muſt be aſcertained and ſubſtracted from the actual product of the aſſay of the ore, to which it neceſſarily muſt have adhered from the lead that was added.

*Waſh-ores*, which are interſperſed in ſtones and matrices of ores, muſt be previouſly freed from them as much as poſſible, then ſtamped tolerably fine, waſhed and roaſted. An account haivng been taken of the loſs ſuſtained by the ore in the waſhing and roaſting; a quintal of the roaſted ore is to be weighed out, and one quintal of glaſs of lead, (compoſed by fuſing one part of waſhed flints with two parts of litharge) and twelve of granulated lead are to be added to it. For the reſt, the proceſſes of ſcorification and cupellation are to be conducted, as deſcribed above.

*Refractory ſilver ores*, which cannot be waſhed, muſt firſt be expoſed for ſome time to a red-heat, and roaſted. After this they are to be mixed with the very ſame ingredients, and thoſe in the ſame proportion, as have been mentioned in ſpeaking

of the wash-ores. It must be observed however that they require a brisker fire in the fusion and scorification of them by lead, and that sometimes a red-hot billet must be laid in the muffle just before the capsule; by which means the ore will be the more readily brought to fuse. The work thus obtained is then to be cupelled.

The process for *assaying various kinds of earths and stones, for silver*, is as follows: one quintal of these is to be mixed with the same quantity of glass of lead, and precipitated and cupelled with twelve quintals of lead, in the manner described above. Or these three ingredients are to be mixed together in equal parts, put into a crucible, and covered with common salt, and the whole brought to perfect fusion; or one part of these stony substances may be fused to glass in a crucible with two parts of litharge or minium in a forge-fire; which glass is afterwards to be powdered, mixed with twice its quantity of black flux, then fused afresh, and the regulus of lead thus obtained submitted to the cupel.

The foundation of these methods of assaying consists in these particulars; 1. that the lead is gradually vitrified by a violent fire, especially when mixed with stony substances, whence is produced a glass of lead, by which again stony matter of all kinds, and all base metals indiscriminately are vitrified, and converted into slags. Hence, the scorias produced in the precipitation by lead are so heavy, and yet are nothing else than a stony substance, or the matrix of an ore, dissolved by glass of lead. Somewhat more lead however must be employed in the precipitation, than is necessary for the scorification of the ore; for in this operation there must remain part of the lead unvitrified which dissolves the gold, silver and copper contained in the ore: 2. that all metals do not mix with lead, as for example, iron. Some, when mixed with lead, are volatile in the fire, and in part fly off with it in the fumes; such as copper, tin, and all the semi-metals; in part they are vitrified together with the lead in the fire, and are carried with it into the substance of the cupel, so that only the gold and silver are left behind in the cupel *.

Mere *Gold ores* are among the uncommon productions of nature; since gold is for the most part found either native or blended with other mineralized metals;

* Even in the early age of *Ezekiel*, the extraordinary fixity of silver was not unknown to this prophet (Kings xxii. 18.) and *Diodorus Siculus* describes the purification of it from other metals, though still in a very inaccurate and inartificial manner: on the other hand, *Geber* has long ago delivered down to us instructions upon this subject, drawn up with much greater skill and precision.

these,

these, however, may be treated the same in every respect as the silver ores: or, a quintal of ore may be roasted, mixed with two of black flux, one of glass gall, or sandiver, antimony, and iron-filings, of each half a quintal, put into the crucible, covered with salt, and fused together. When the fusion is finished, the cover is to be taken from off the crucible, and twelve quintals of lead to be added to the mixture; the crucible is then to be covered again, and the whole exposed to the blast of a pair of bellows, till the ingredients are well incorporated together. The crucible is afterwards to be taken out, and the lead put into the cupel.

Having now shewn how each metal is to be smelted in little from its own ore, we have yet to mention in what manner all *kinds of metals* may be *assayed for silver*, as it often happens that the smelted metals still contain a portion of it.

With this view the *regulus of antimony* is scorified in a test or capsule, in a very gentle heat with eight, or ten times its quantity of lead, till the colour of the fumes is altered, which, in this case, is usually brown, and the grey fumes of lead appear; when it is suffered to stand half a quarter of an hour longer. The lead is then separated from the scorias, cupelled, and the silver button weighed. *Zinc* is calcined by itself in a crucible, and a quintal of it scorified and cupelled with two quintals of glass of lead, and twelve of lead. *Bismuth* is mixed with from four to six times its quantity of lead, and in every respect treated like regulus of antimony; the fumes arising in the precipitation of it by lead are only inclining to brown.

To *assay iron for silver*, to half a quintal of iron, which must be reduced to filings, or else beaten out very thin, one quintal of triturated sulphur is to be added, and put into a capsule rubbed over on the inside with chalk, which, after being covered with another, must be placed quite in the fore-part of the assay-furnace, and roasted with a gentle heat. When the sulphur is expelled from it, the residuum is weighed out with eight times its weight of lead for the assay, scorified in the capsule, and then submitted to cupellation. The assay of *lead* for silver is easily conceived from what has been mentioned before; but in order to assay *Tin* with the same view, half a quintal of it is to be weighed out, and set to calcine in a capsule in the assay-furnace with two quintals of lead. This is to be set forwards in the mouth of the furnace, so that it may become a little red, when, after a short time, the tin is seen to cover the surface of the lead in the form of a grey calx. This grey calx is to be taken off by little and little with an iron

ladle, and pushed towards the sides of the capsule till the whole is calcined. The capsule is then to be taken out, and all the calx of tin collected together, which is then to be mixed with an equal or twice the quantity of glass of lead, and again put into the furnace in a capsule. After which, a quantity of lead is to be added to it, equal to ten times the weight of the calx of tin, and the whole to be scorified and cupelled, like a refractory silver ore. Copper, with a similar view, is to be reduced to filings, or beaten out into thin plates, which are to be cut into small pieces with a pair of scissars, and half a quintal of them are to be cupelled with sixteen quintals of granulated lead *.

The various *sorts of silver which differ with regard to fineness*, are to be assayed and refined in the following manner. The silver is first to be rubbed upon the touch-stone, in order to ascertain by this means, what is the proportion of copper contained in it, so that the quantity of lead to be added, may be determined afterwards. This is done in the following manner:

| | dwt. | gr. | | dwt. | gr. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Silver of | 12 | 0 | | | | requires from | 3 to | 4 | times its weight of lead. |
| | 11 | 6 | | | | | 5 | 6 | |
| | 10 | 12 | | | | | 8 | 9 | |
| From | 9 | 18 | to | 9 | 0 | | 12 | 13 | |
| | 8 | 6 | | 7 | 12 | | 13 | 14 | |
| | 6 | 18 | | 6 | 0 | | 14 | 15 | |
| | 3 | 0 | | 1 | 12 | | | 16 | |
| | 1 | 12 | | 0 | 18 | | | 20 | |

Now, as many cupels as will be wanted being made hot, the lead, in the first place, is put into them, and when this begins to *circulate*, the silver also, cut into small pieces, is put ino a small brass pot. With respect to the fire, the operator must be regulated by the fineness of the silver; for the finer the assay is, the brisker the fire must be, and the more copper there is contained in the assay, the lower

* In order to assay Zinc for silver, an assay quintal of the zinc must be calcined in a test under the muffle, and the fire is to be increased till the zinc is inflamed; then the flowers are to be separated very carefully from the burning zinc till they cease to arise. This being done, the remaining mass may be smelted with two assay quintals of glass of lead and twelve of granulated lead; after which, the scoriæ must be separated from the metal, and the silver button weighed. It is of consequence, that the zinc, previous to its being smelted with lead, be calcined till it ceases to burn; because, if mixed crude with the lead, it would set fire to this latter metal, by which means a considerable quantity of silver might be lost. [D]

the

the fire is to be kept. But all affays agree in this, that they all ought to *lighten* hot, and efpecially fine filver, becaufe it is very apt to fix, before it is cleared of the other metals. In other refpects, the procefs is the fame as in common cupellations; and the fmall portion of filver contained in the lead, muft by no means be omitted in the calculation.

It is true, we have occafionally mentioned before, that ten parts of lead are able to deftroy one part of copper, and hence it might be thought unneceffary to ufe more than twelve times the weight of lead for an allay of copper of eleven penny-weights and fix grains; but it muft be confidered, that filver, when mixed with copper, attracts the latter very powerfully towards the end of the operation, and protects it in fome meafure from the action of the lead; whence alfo, the laft portion of copper is not fo eafily feparated from it; for this reafon, a greater quantity of lead muft be ufed for the explufion of the copper from the filver, than would be neceffary for the mere deftruction of the copper; and notwithftanding this, the button will commonly ftill contain fome copper.

In the methods hitherto defcribed, filver and gold may be feparated from all femi-and bafe metals; but thefe two noble metals, which are often united together, muft be feparated from each other by different means, and for this, there are chiefly two ways, viz. the *dry* and the *humid* way.

The method of proceeding in the *humid* or *moift* ways is as follows: When the filver to be examined contains but a fmall quantity of gold, of which a judgment may be formed by rubbing it on the touch-ftone, a little of it is diffolved in aqua fortis that has been previoufly purified by precipitation, when the gold contained in it is left behind undiffolved, in the form of a brown or black calx. But when there is a greater quantity of gold in the fample than of filver, and the filver confequently *abounds in gold*, the gold is feparated from the filver as perfectly as can be done, by folution in aqua regia. In the firft cafe however, a refiduum or *arrearage* of filver remains behind united with the undiffolved gold, and in the fecond inftance a refiduum of gold is left in the undiffolved filver. The caufe of this is, that gold and filver defend each other mutually from the action of the menftruum, when part of the one is enveloped in an exceeding fmall quantity in the other. Thefe arrearages, according to *Schluter* and *Cramer*, fcarcely amount to $\frac{1}{150}$ or $\frac{1}{200}$ in the mark. By this obfervation, it has been difcovered farther, that neither aqua fortis nor aqua regia can effect a perfect feparation in an allay of gold and

filver,

ſilver, unleſs theſe metals be mixed together in a certain proportion. But when one part of gold is allayed with three parts of ſilver; ſilver may be diſſolved by aqua fortis purified by precipitation; ſo that only the gold with a very ſmall arrearage of ſilver ſhall remain behind undiſſolved. This is called *ſeparation by quartation*, or ſimply *quartation*. Now, in order to attain this end, the quantity of gold contained in the ſilver muſt be firſt aſcertained by the touch-ſtone. In caſe that the gold ſhould amount to more than one-fourth, ſo much ſilver muſt be added to the maſs, and fuſed with it, as is ſufficient to produce the above-mentioned proportion. A more circumſtantial deſcription of the proceſs may be found in more diffuſive writings upon the ſubject of aſſaying. To this head alſo muſt be referred the ſeparation of gold from platina, which is effected by pouring into a ſolution of this allay a ſolution of ſal ammoniac, when the platina is precipitated alone, while the gold is thrown down ſeparate by a ſolution of martial vitriol. The *ſeparation of gold in the dry way* cannot be attempted in little, but only in conſiderable quantities; it therefore belongs rather to the operations carried on in the great at the ſmelting works.

Finally, it remains for us to give a ſhort ſketch of the method of *aſſaying of ores* in the humid way. With this method *Bergman* firſt made us acquainted, in a treatiſe expreſsly written on the ſubject *. This proceſs is advantageous, chiefly in ſuch caſes, in which three-fourths or more extraneous metals are preſent at the ſame time in an ore, and frequently, alſo, various kinds of earths occur in it, of which no knowledge can be acquired in the dry way. In this caſe, we ſhall receive the greateſt aſſiſtance from that which has been laid down above in the examination of the different kinds of earths; and the knowledge of the preparation of the metallic neutral ſalts, ſo far as it teaches us by what means each metal is beſt diſſolved, cannot by any means be diſpenſed with. An ore, therefore, that ſhall be aſſayed this way, muſt be reduced to a fine powder, and according to the kinds of metal principally contained in it, is to be digeſted either with the vitriolic, the nitrous, or the marine acid, or with two of theſe acids mixed together, in a quantity ſufficient to cover it; the liquor is to be decanted, and this proceſs is to be repeated till in moſt inſtances a white quartzy earth remains behind. Sometimes too the extraction muſt be made with different acids, and each extract be aſſayed ſeparately. In this caſe the ſolutions are to be

* Opuſc. Phyſ. Chem. Vol. II. p. 394—454.

filtered and precipitated with different precipitates, and finally, the precipitates are to be accurately aſſayed, and their nature and weight determined.

As each ore, according to the nature of its contents, requires a particular mode of treatment; and to deſcribe each of theſe individually would take up too much of our room, I muſt beg leave to refer the reader to the abovementioned work itſelf; and ſhall adduce one example only for all: viz. The *aſſay (viâ humidâ)* of the *white ſilver ore* in which together with the ſilver, are found ſulphur, arſenic and copper. One quintal of this ore reduced to a fine powder, is to be boiled gently for the ſpace of an hour, in a phial with twelve quintals of diluted nitrous acid. As ſoon as the powdered ore, which is of a black colour, is put into the acid, it emits a ſulphureous ſmell; part of it is diſſolved with efferveſcence, and a white reſiduum remains at the bottom. The liquor filtered off from it contains the ſilver and copper, from which the *ſilver* is to be precipitated, by the addition of more copper which has firſt been accurately weighed. The *copper* may be precipitated by iron or mild alkali, but at the ſame time, the part of the precipitant taken up by the menſtruum, muſt, during the precipitation, be deducted from the weight. The reſiduum of the ore muſt now be boiled with marine acid, and the *arſenic* precipitated with water, which however will ſtill contain a ſmall quantity of marine acid, which it is diſpoſed to retain with obſtinacy. After this there will be nothing left behind in the reſiduum but the *ſulphur*, which may be farther tried by volatile alkali, in order to diſcover whether it ſtill contains any copper, or muria of ſilver.

Upon the very principles laid down for aſſaying in the dry way, depend alſo the *operations carried on in the ſmelting works*, the object of which is the production of metals in the great. Here the metals are in like manner to be ſeparated from all heterogeneous particles, but moſtly by means of very different and cheaper additions. The means requiſite for this purpoſe are either *mechanical* or *chemical*.

To the *mechanical mode of ſeparation* may be referred the *picking out* of the ore, that has been extracted from the mines, from the uſeleſs ſtony part, the pounding of it into ſmall pieces, of the ſize of a walnut, and the pulverizing of them farther in mills conſtructed for the purpoſe, and furniſhed with large ſtamps clouted with iron. The ores are then waſhed, by which means the light earthy particles are waſhed over upon waſh-hearths deſtined for this purpoſe, and ſeparated from the heavy powder containing the ore, which in this operation remains at the bottom.

The reſt of the operations are *chemical.* The firſt that takes place is the *roaſting,* in which the ores as well as the *ſtamp-ſtuff* prepared from them, are either directly or indirectly expoſed to the fire, in ſuch a manner as to be calcined without fuſing. The intent of this operation is: 1. to render the ores friable: 2. to ſeparate the noxious volatile parts: and 3. at the ſame time to calcine the baſe metals, that theſe latter may the eaſier be ſcorified in the ſubſequent fuſion. This end is the more eaſily attained by the *dreſſing of the ores,* as it is called, an operation that conſiſts in the addition of various bodies, which promote as well the calcination as the fuſion, and are called *fluxes.* Under this head come *lime-ſtone, feldt-ſpar, fluor-ſpar, quartz* and *ſand, ſlate, ſlags* and *pyrites.*

The *fuſion* has for its object the perfect ſeparation of the metallic from the earthy or ſtony parts of the ore. This cannot be brought about any other way than by deſtroying the coheſion ſubſiſting between the two parts. This is effected by the reduction of the metal, and by putting the earthy parts into a ſtate in which they can no longer unite with the metal. The chief condition requiſite for accompliſhing this is the fuſion of the whole maſs.

With this view particular attention ſhould be paid: 1. to the *ore* itſelf, whether it be poor or rich, whether of eaſy or of difficult fuſion, and what kind of ſtony matter is blended with it: 2. to the *materials* and *inſtruments* by which the fuſion is accompliſhed. The former of theſe conſiſts of the additions mentioned before, which are to be choſen according to the different views of the operator, and the nature of the ores. Thoſe fluxes which are deſtined for the firſt rough ſeparation of the ore from its matrix, (as in the caſes of the matts for inſtance, of copper or lead) muſt be adapted to the nature of the ſtony part or matrix. Sometimes alſo different ores that are found in different matrices, may be mixed together, and by this means the more eaſily fuſed and ſcorified. In the ſmelting, regard muſt be had likewiſe to the nature of the metal itſelf. Thus the iron ores, on account of the argillaceous earth they contain, require calcareous additions; the copper ores, rather ſlags or vitreſcent ſtones, than calcareous earth; and the lead-tin-and ſilver ores, by reaſon of the calcareous matter mixed with them, alſo rather affect vitreſcent ſubſtances, or, in preference to theſe, ſlags. For the more calcined metals, phlogiſtic reducing additaments muſt be uſed. Next to this, recourſe muſt be had to ſuch precipitants as will unite either with the heterogeneous parts of the ore, or with the metals to be ſeparated. With reſpect to all theſe points,

œconomy muſtbe uſed in working in the great. The chief inſtruments are the *furnaces*, or which ſeveral kinds are in uſe, and of which the deſcription muſt be looked for in other works.

Beſides the general principles, ſeveral circumſtances occur in the method of procuring each individual metal, which ſhall now be briefly mentioned.

*Manganeſe*, *Cobalt*, *Arſenic* and *Nickel*, are obtained in the ſmelting works, for the moſt part indirectly and adventitiouſly, in treating different ores in the great, and not wrought for the metal. *Manganeſe* is dug up juſt in the ſame ſtate in which it is found in its beds. *Cobalt** is obtained either in its proper ores, or from the reſiduum left after the ſmelting of biſmuth out of its ores, and immediately uſed for producing a blue colour. *Arſenic* is collected in a peculiar kind of flues or chimneys, and in the form of a powder, from the different ores which contain it, (ſuch are ſome ſilver, cobalt-and tin-ores), by roaſting them in furnaces of a particular conſtruction, of which the firſt were built by *David Haidler*, at *Joachimsthal*, in the ſixteenth century. This powder, which is of a grey colour, is afterwards ſublimed afreſh, with the addition of aſhes, in edifices, that are called *poiſon-houſes*, built for this purpoſe in appropriate veſſels, and by this means reduced to ſolid and white cryſtalline arſenic. *Nickel* is commonly found mixed with ſome other metals, in the ſubſtance called *Speiſe*, which remains after the fuſion of ſmalt. *Antimony* is ſeparated from its ores without any particular artificial treatment, and without the addition of any extraneous matter, merely by ſmelting it; on which occaſion no other caution is to be obſerved than merely to avoid the free acceſs of air. The crude ore is broken to pieces, and put into large pots perforated at the bottom with ſmall holes, through which, being melted by fire laid upon the top of it, it runs into ſmall pots placed underneath. *Zinc* is procured in the great, in *two different ways*. The firſt is the moſt common, and according to this it is obtained adventitiouſly, in the ſmelting of ſuch copper or lead-ores as contain zinc or blend. With this view, in the works at Rammelſberg, to the front wall of the ſmelting furnace, over the hearth, a frame of ſlate is fixed, which is called the *Seat* of the zinc, upon which the ſmelted zinc is depoſited, and from whence it is collected. The other method conſiſts in the diſtillation of the cadmia fornacum or elſe of native calamine, after it is mixed with powdered charcoal, in ſtone or iron retorts, with a violent fire.

* A very large cobalt mine has been lately diſcovered by *M. B. R. Geyer*, in Sweden, not far from Weſterwyk; it is pure, and yields the moſt beautiful glaſs. [E]

Zinc in its metallic ſtate is a very volatile metal, and, when made red-hot, burns with a flame; and is thus calcined afreſh. It muſt therefore neceſſarily be made to paſs into a metallic ſtate from its ore, in cloſe veſſels. The zinc found in this latter condition, however, is commonly uſed, without undergoing any particular previous ſeparation, to greater advantage for the formation of braſs. The name of zinc firſt occurs in *Baſil Valentine*.—*Biſmuth*, whether found native in its proper ores, or elſe mineralized with arſenic and ſulphureous acid, may be obtained by fuſion only, in the three following ways: 1. With the ſame apparatus as has been mentioned for antimony, only with a rather ſtronger fire: 2 by mere ſmelting in pits, placed upon an inclined plane, or in crucibles ſo contrived, that the ſmelted biſmuth may flow down on to the hearth, or into a veſſel placed underneath them: or 3. upon roaſting grates, where the ores of cobalt, containing biſmuth, are put upon cleft fire-wood, in the open air, and roaſted, by which means the biſmuth is ſmelted out of them.

In the proceſs for procuring *mercury* in the great, the nature of the ſtony matrix is principally to be conſidered. The mercury itſelf, is commonly mineralized by ſulphur alone, and in this combination conſtitutes native cinnabar, which in the ores is interſperſed among earths of different kinds. In this caſe conſequently the principal view of the operator muſt be directed towards diſengaging the mercury from the ſulphur. But as the operation of roaſting cannot take place with reſpect to this volatile metal, the diſengagement of the ſulphur muſt be effected by means of fixed bodies, that bear an affinity to it. Now this is the caſe with lime-ſtone. When therefore the ores have been prepared by ſtamping, waſhing and decantation, ſhould their nature require it, they are to be mixed with lime-ſtones; but when the matrix of the cinnabar-ores is of a calcareous nature itſelf, this addition is unneceſſary: thus the quickſilver ores of Idria and Friuli do not need any ſuch addition. The mercury is then to be diſengaged by diſtillation. For this purpoſe, in the dutchy of Deuxponts large iron retorts are uſed, a number of which is put into the ſame furnace. In Idria, Almaden and Friuli, the calcining furnace itſelf ſerves for the belly of a retort; and the apertures contrived in it, with the aludels fixed to them, and depending from the ſide, form the neck; while the chamber, into which the aludels in this inclined poſition convey the fumes, repreſents the receiver.—Of the mode of obtaining *Platina* nothing can be ſaid with certainty: It is thought to be the reſiduum of the various gold ſtamp-ſtuff, or auriferous ſand, after the gold has been extracted by triture or amalgamation.

The

The genuine iron ores muſt firſt be roaſted, in order to diſſipate the ſulphur, and ſometimes alſo the arſenic contained in them. All ferruginous ſtones, as alſo the lake---bog---and moor-ores, are exempted from this operation. For the ſmelting itſelf, and the promotion of it in the great, means muſt be employed very different from thoſe that are practiſed in the ſmall way. For promoting the flux, lime-ſtone, calcareous marle, different ſpecies of ſaxa, feldt-ſpar and ſlags, may ſerve. The reduction is effected by intermixing ſtrata of ore and charcoal alternately, which latter however muſt be taken in a proportion adequate to the quantity of the ore. The iron thus obtained is either *red-ſhort*, *cold-ſhort*, or *malleable*.* The real

* *Malleable Iron* is divided by the celebrated *Rinman* as follows: 1. *Perfectly malleable* and *good*, or that which may be extended under the hammer, both cold and red-hot, without contracting flaws or breaches at the corners; and which, with proper care, may be welded in a welding heat without breaking or becoming brittle. 2. *Half-malleable*, or that which will bear gentle hammering only, but burſts in the corners from a ſtronger.—The moſt remarkable varieties of this are as follows: (*a*) *Red-ſhort*, or that which is tough, and may be forged cold, and alſo in a white heat, but in a red heat cracks under the hammer. (*b*) *Cold-ſhort*, or that which may be forged in a ſtrong red-heat, but is brittle when cold. (*c*) *Unmalleable* and *crude*, or that which cannot bearing hammering either hot or cold, and approaches to the nature of crude or caſt iron, which however is not meant here. (*d*) *Unequal*, or that which is ſoft and hard in one and the ſame bar; or which contains either *crude iron*, *grains of ſteel*, or elſe what are called *flint grains*, (flintkorn) intermixed with its ſubſtance; iron of this laſt quality is termed *pinny* by the workers in iron and ſteel.

The varieties of *perfectly* and *half-malleable Iron* are almoſt innumerable: we ſhall here mention ſuch only as are known by certain denominations. (A) *Hard Iron* may be perfectly malleable. In order to be extended or beat out, it requires only harder and a greater number of ſtrokes with the hammer, and is either *ſteel*, or *mixed with ſteel*. Of this there are ſeveral varieties. (*a*) *Hard* and *ſtrong*, which will bear forging and bending: as for inſtance, the iron of Dannemora, Oregrund, &c. in Sweden. (*b*) *Hard* and *brittle*, or that which will bear hammering, but not bending, and is commonly mixed with ſteel. (*c*) *Hard* and *tough*, or that which will bear bending both cold and hot; ſuch is the beſt iron from Norberg. (*d*) *Hard* and *wild*, or that which may be forged cold, and in a certain degree of heat; but breaks in a white and welding heat. (B) *Soft Iron*, which yields, both cold and hot, to the gentler force of the hammer and file. This may be (*a*) *Soft* and *tough*, which will bear much bending before it breaks. Of this kind is the *Oſmunds* and other ſorts of Swediſh iron. (*b*) *Soft* and *brittle*, or that which is eaſily forged while hot, and filed when cold; but, when handled roughly, breaks with a ſhining ſurface, and conſequently is of the cold-ſhort kind. (*c*) *Soft* and *ſpongy*, may be forged both cold and hot, into thin plates, and likewiſe drawn out into wire, but eaſily breaks, when bent, with ſhort fibres. This iron is produced chiefly from ſpongy, micaceous, hæmatitic ores, of a light grey colour. (C) *Tough Iron*, or that which is perfectly malleable and fit

real cauſe of the defective quality of red-ſhort and cold-ſhort iron, which formerly was aſcribed to a greater or leſs proportion of ſulphur contained in them, is not fully diſcovered

fit for all kinds of ſmith's-work; it may likewiſe be bent, without heating, ſeveral times backward and forward, in the form of bars or wire, before it breaks. It is either *tough* and *ſoft*, or *tough* and *hard*, when it comes under the following head D. From the beſt iron of this ſort, the fineſt wire is drawn, and of the greateſt length. (D) *Stiff* and *ſtrong Iron* which bears much bending, and wears well; at the ſame time that it appears hard to the hammer and file. The Smiths call it *tough-hard*; it is not mixed with ſteel, and like C is uſed for making wire. A wire of this kind of the ſame thickneſs as one from C will bear a greater weight. (E) *Cloſe* or *denſe Iron*, which is the oppoſite to ſoft and ſpongy (B c). This muſt be of an equable texture throughout its whole maſs, not burſt in hammering, nor in poliſhing exhibit any ſtripes or ſpongy places, much leſs muſt it be what is called *pinny*, and at the ſame time it ſhould be tough-hard, or ſtiff and ſtrong; in ſhort it muſt poſſeſs the properties of the beſt iron.

The *beſt* iron is that which (1) on being filed and poliſhed exhibits an equable light-grey colour: (2) that is the pureſt and denſeſt, which poſſeſſes the greateſt ſpecific gravity. The toughneſs and ſtrength of iron, however, cannot be diſcovered by this means. (3) When two pieces of iron ſimilar in form and equal in weight are preſented to a well-armed magnet, that is the pureſt which holds the faſteſt. (4) It is longer in ruſting in the open air, and when at laſt it does, it contracts a thin coat of ruſt, which is ſpread equably over its whole ſurface. Thus, for inſtance, a gun-barrel which exhibits an equable brown ruſty colour in every part, conſiſts of homogeneous iron. (5) Fire from the loweſt to the higheſt degree of heat, is the moſt certain teſt for iron. Thus, that iron is eſteemed the ſtrongeſt which (*a*) in the loweſt degee of heat, or, to ſpeak more properly, in the cold, can bear to be the moſt hammered when cold, and be bent the moſt without breaking. (*b*) Iron which is the moſt expanded, or augmented in bulk, when expoſed to heat, and conſequently contracts the moſt in the cold, is the pureſt, for this reaſon, that the metal which requires the greateſt heat for its fuſion, is likewiſe ſubject to the greateſt expanſion and contraction. Now, the pureſt iron, as experience ſhews, requires the greateſt degree of heat for its fuſion. If a bar of ſoft iron be welded with a piece of hard iron or ſteel, of an equal ſize, and cooled haſtily while it is red-hot, the maſs becomes crooked, and bends towards the ſoft ſide, becauſe this contracts moſt. The iron therefore which, in cooling in water, is the leaſt warped, is the moſt homogeneous and uniform. (*c*) The harder the iron, the eaſier in general, it exhibits various colours on its ſurface, when expoſed to heat, but particularly blue. Therefore if iron acquires a blue colour in different parts and places ſooner than the whole does, this indicates a mixture of hard and ſoft iron; the ſoft parts do not turn blue, till this colour has begun to diſappear on the hard parts. (*d*) In a ſtrong red-heat, the ſofteſt and tougheſt iron conſumes and burns away moſt; it likewiſe produces the ſofteſt and leaſt ſharp ſcoriæ. In (*e*) a ſtrong welding or melting heat, the pureſt iron throws out white, bright, crackling ſparkles, which an experienced eye eaſily and with certainty diſtinguiſhes from the red, coarſe, heavy ſparkles of impure, and particularly red-ſhort iron, and by this means can diſcriminate the iron itſelf,

difcovered as yet: but it begins to be more probable now, that manganefe, or phofphoric acid, is the latent caufe of it. By that treatment, in which the extraneous parts are the moft perfectly feparated, the greateft quantity of phlogifton united with the iron, and the earthy parts moft completely vitrified, the beft iron will certainly be obtained. For I have no doubt but that nature, to fpeak in general, affords but one kind of iron; and that all iron ftones, with proper and fkilful treatment, muft yield malleable iron, although we are as yet unacquainted with a univerfal method of proving this, with refpect to all ferruginous ftones.

*Lead* is commonly mineralized by fulphur, the feparation of which confequently muft be attended to. This is effected by roafting and then fmelting the ore with fuch additions as the fulphur bears a great affinity to, among which are lime, its fpars and iron. To pure lead-fpar, a mere reducing fubftance only is requifite to be added. Moft lead contains filver, and on that account muft be fubjected to cupellation.

itfelf. Pure iron likewife bears a ftronger heat, before it throws out fparkles, and in this cafe appears of a milk-white colour. It alfo may then beft be forged, and united with other kinds of iron that are fubjected to an equal degree of heat. (*f*) When prevented from coming into contact with the coals, the pureft and moft malleable iron either does not fufe at all, or at leaft with more difficulty than any other fort. In its malleable ftate, therefore, it does not perfectly mix with any other metals; but when the air has accefs to it, together with combuftible matter, (by which means it is either converted into fteel or pig-iron) the fufion becomes practicable. (*g*) Pure common foft iron, after being made red-hot, becomes lefs hard by being extinguifhed in water, than when it has been left to cool in the air; it then bears hammering and bending, and is not found to be harder in one part than in another, by the file or hammer. (6) Aqua fortis and other corrofive liquors fhow a difference in iron. If it be laid in any of thefe an hour or two, foft and homogeneous iron appears of a filver-white hue over its whole furface, the hard fort, of a dark-grey colour, and blackeft; the mixed variegated, dark, fhadowy fpots, generally indicate crude or cold-fhort Iron. (7) In the cementation of fteel, the properties of the iron appear extremely evident, and its defects plainer than before. Soft, fpongy iron of a foliated fracture produces in the cementation of fteel, blifters as large as walnuts; while denfe and ftrong iron of a finely-granulated fracture, exhibits few blifters or none on its furface. Red-fhort iron produces a ftill more red-fhort fteel, and cold-fhort iron yields a fteel fo brittle that it can neither be wrought hot nor cold. Flaws, fifures, and an uneven grain are much more plain and diftinct in cemented fteel than in Iron. Soft iron produces ftill fofter fteel, and the Swedifh iron of Oregrund and Dannemora would hardly have been fo well known to the Englifh, had they not had the trial of it in the cementing of fteel. [E]

In

In *tin ores*, the chief attention of the artiſt is to be directed towards the ſeparation of the ſulphur and arſenic, and the reduction of the metal. This intention is promoted by roaſting, ſtamping, waſhing, and by a ſecond more intenſe roaſting in what is called the *calcining furnace*. After which the ore is mixed with charcoal, in the due proportion, and ſmelted with proper caution, ſo that the ſmelted metal be not conſumed, or become brittle by a too intenſe heat. To refractory ores, the ſcoriæ of tin only muſt be added by way of flux*.

No metal is ſeparated with more difficulty from its ore, ſo as to be exhibited in its pure ſtate, than *Copper*. On account of its intimate combination with ſulphur, it muſt be repeatedly roaſted, fuſed and precipitated. Theſe precepts however do not affect the pure copper ores which need not be roaſted, but may be ſmelted directly. They are rather meant of ſuch ores as require roaſting, with a view to conſume their redundant ſulphur. In the firſt fuſion of the ore ſubſequent to this, which is called *crude fuſion*, a product is obtained, that is known under the appellation of *matt*, and conſiſts of a metallic mixture of copper, iron and ſulphur, from which the ſtony matrix only has been ſeparated. After this it muſt be roaſted afreſh, partly in order to diſſipate a farther portion of the ſulphur, and partly to calcine the iron contained in it; and then a ſecond fuſion takes place, the product of which is called *black copper*. Now from this the pure copper cannot be obtained but by a third operation, which is called *refining*, and the product *red* or *refined copper*. This is performed either upon refining hearths, where the copper is ſurrounded at top and at bottom with charcoal, and urged with bellows in ſuch a manner, that by means of fire and air, the metals and ſemi-metals with it, are converted either into fumes or ſcoriæ. In this operation, an addition of $\frac{1}{20}$ or $\frac{1}{40}$ of caſt iron may be advantageouſly uſed for ſeparating the ſulphur, by reaſon of its greater affinity with this ſubſtance. Or with a view of attaining the ſame end, two, three, or four parts of lead are added to forty of black copper, by the ſcorification and vitrification of which, the reſt of the baſe metals alſo are ſcorified at the ſame time, and the copper is freed from ſulphur.

* The method of ſmelting tin out of its ores, uſed in Cornwall, is as follows: They mix the richeſt ores with the pooreſt, and the whole with the fifth part of powdered cawk. Of this mixture they put in ſix hundred weight at once, mix it at different times with a hook, and ſtir it up after ſix or ſeven hours are elapſed: the melted tin runs into a great ſtone jar ſtanding before the furnace: they then break into pieces the tin thus obtained, and fuſing it again without any farther addition, form blocks of it, of three hundred weight each block. [D]

*Silver* is generally found very ſparingly in its ores, and therefore can hardly be ſo accurately collected by itſelf from the great quantity of ſtony matter mixed with it, as its walue requires it to be. Therefore ſuch materials muſt be uſed as will diſſolve the ſilver diſperſed in the ore, unite with it and collect it into one maſs. This may be effected by means of *mercury* and *lead*. Mercury is uſeful in ſuch caſes only when pure native ſilver is mixed with ores and ſtones. For this purpoſe all the uſeleſs ſtony matter muſt firſt be ſeparated, and that which is good be pounded ſufficiently ſmall, and then ground with mercury and water, in mills of a particular conſtruction, called *Amalgamating mills*. The redundant mercury is preſſed out from the amalga produced in this operation through leather, and the remainder diſengaged from the mercury ſtill adhering to it, by means of a retort. This is the procedure with reſpect to the ſilver ores dug from the Spaniſh ſilver-mines in America. Lead performs exactly the ſame office in ſimilar caſes, in the dry way. The galenas that contain ſilver are of ſuch a nature, that they may be ſmelted and cupelled either with or without a previous roaſting; in the former caſe, by the addition of iron; and in the latter caſe, with the addition of litharge. The poorer ſorts of *pyritous ores*, contain little ſilver, and alſo little or no lead; but inſtead of this, iron may be fuſed with the ſcoriæ of lead. The product of this fuſion is a ſulphurated *lead matt*, which conſiſts of lead, iron, ſilver and ſometimes of other metals beſides. This muſt farther be roaſted, fuſed afreſh and cupelled. The pellicle, which in the beginning of the cupelling in the great, appears upon the ſurface of the fuſed metal, conſiſts of iron, copper and other refractory ſcorified metals. When this is removed, the *litharge*, which muſt in like manner be ſeparated by little and little, appears in tolerably thin fuſion. Beſides the lead ores, the major part of the *copper ores* alſo contain ſilver, from which again the ſeparation of the ſilver muſt be effected, though differently with reſpect to the circumſtances. This conſiſts in ſmelting the ſilver from the copper, by means of lead, and is called *Eliquation*. It is undertaken with the yet ſulphurated crude copper, and about $2\frac{1}{2}$ or $2\frac{3}{4}$ of quintals of lead are fuſed with $\frac{3}{4}$ of a quintal of copper. This firſt part of the operation is called *refreſhing*. The flat cakes of ore obtained in it, called *eliquation cakes*, are then ſet upright one beſide the other, in a furnace of a particular conſtruction, called an *eliquating furnace*, and room is left for coals between each of them. By the heat imparted to them the whole of the lead is then ſlowly melted out of them, which at the ſame time carries along with it the ſilver contained

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in the copper, and the whole is collected together in a channel made in the solid and inclined bottom. This process may be accounted for upon the following principles: 1. That lead has a greater attraction for silver than for copper, and so again the affinity of silver is greater to lead than to copper: 2. that the lead in itself being of easier fusion than copper, and not becoming refractory by the small addition of silver, and at the same time when brought into fusion by a low degree of heat, not dissolving the copper, the silver smelted out on this occasion is united with the lead alone: 3. that sulphur is more inclined to unite with copper than either with silver or with lead; for this reason, the copper is subjected to this operation, while it is still in its sulphurated state, for the purpose of promoting the separation of the silver from it. In the abovementioned eliquation, strictly speaking, the greatest part of the lead only is smelted out; and the cakes of ore remain behind exhausted, in which state they are called *Eliquated cakes*. These must now be forced by a more violent fire, to yield all the remainder of the lead mixed with silver. This operation is called *Eliquating by a second fire*; and is performed in furnaces built for this purpose. The copper which now remains behind is to be treated farther like other black copper, and reduced to red copper: but the lead mixed with silver, must be cupelled in the manner frequently described before. All the *litharge* produced in these operations is either sold in this state, or together with the tests and an admixture of charcoal, smelted again to *cold lead*, and used again for the same purpose as that to which it has been just applied. The argentated lead produced in this operation, is cupelled in tests, as has been frequently mentioned before. But as the silver obtained in this manner is not pure, it must yet be *refined*. This consists in another short cupellation, with a strong fire; in which, to one hundred marks of silver about two marks of lead are to be added, and the silver brought to *lighten* with a violent fire.

The process for procuring *gold* is for the most part the same as silver. Native gold is obtained from the sand of many rivers, by washing the sand. But if it be interspersed in different stony matrices, these are calcined, pounded, washed, and the gold is obtained from them by amalgamation with *mercury*. In the other way, it is separated by means of lead from the metals contained in them, in the same manner as silver is out of various other ores. Many lead--copper--and silver ores, for instance, yield it, and it is commonly obtained in the end united with a larger quantity of silver. The manner of separating it from them by parting

by

by aqua-fortis has been mentioned before. The *separation in the dry way* is performed in the following manner. One part of gold, containing silver, is well fused together with two, three, or even four parts of antimony, and the mass is poured into a cone; when it is cool, the regulus that is at the bottom is separated from it. The antimony that lies at the top, is then to be melted twice more, (each time, with twice its weight of fresh antimony) poured out, and the regulus separated from it. Upon this the three reguli likewise are fused with three times their weight of antimony, poured out, and again separated from the antimony. The metallic regulus, obtained by this means, consists now of regulus of antimony and gold, the former of which must be dissipated in the air, by urging it in the fire, with the blast of the bellows, when the latter metal will remain behind pure and unadulterated. Now all the aforementioned portions of the separated antimony contain the silver that has been separated from the gold, and still a small portion even of the gold; for the obtaining of which provision must be made. This may be accomplished, first, in a capsule, merely by the blast of the bellows; 2. by fusing the antimony with an equal quantity of black flux, and exposing the regulus, thus obtained, to the blast of a pair of bellows; 3. by fusing the whole of the antimony together, and adding as much iron as can be dissolved by it; at the same time to each mark, half an ounce of lead besides is to be added, the whole well fused together, poured out, and the metallic regulus exposed to the blast of the bellows. This operation is called the *fusion of gold by antimony*, a process of which *Basil Valentine* was the first inventor.

To this the *separation of gold in fusion*, otherwise called, *dry parting*, bears a great resemblance. It is used for the separation of gold, that is contained in silver in a small quantity only, as for instance, silver that has been gilded, &c. This operation, however, must be performed in large quantities, viz. of fifty or a hundred marks. The chief point consists in adding something to the silver, containing the gold, which unites with the silver only, and leaving the gold untouched, will at the same time disengage it from its combination with the silver. Now all this is effected by sulphur. When this substance is united with silver containing gold, and the sulphurated silver arising from this combination is fused with a strong fire, it penetrates into the substance of the silver, unites with it, and mineralizes it, but does not act upon the gold, which now, by virtue of its unaltered metallic nature and its gravity, separates from the sulphurated silver, and sinks to the bottom; this effect may be also promoted by the addition of another

metal of eafy fufion. The defcription of the whole operation, which is fomewhat tedious, may be feen in *Schluter* or *Eller**.

Confidered collectively, the metals are applied to various purpofes, and that chiefly in three different forms, inafmuch as they are either fuffered to remain in their *native form*, or are *calcined*, or *mineralized*. What is remarkable refpecting each muft now be mentioned, and is here comprized in a general way, under the title of *Metallic Preparations*.

Previoufly likewife to defcribing the ufes to which the *native metals* may be applied, mention muft be made of the manner in which fome metallic bodies, obtained in the great, may be put into a real metallic ftate; becaufe this is not ufually done at the fmelting works.

The *Regulus of Manganefe* is beft obtained in *Bergman's* method, mentioned at page 397†. *Regulus of Cobalt* is obtained pureft from very dark-coloured fmalt, by fufing it in a ftrong fire with foap and pot-afh. It is obtained lefs pure from the calx of cobalt, by fufing one ounce of it in a forge-furnace, with three ounces of black flux, an ounce of decrepitated common falt, and half an ounce of pitch. The pure regulus of cobalt may be fufed together with all the metals, except arfenic, bifmuth, lead, and filver. The metals from which cobalt is with the greateft difficulty difengaged are arfenic and iron; the feparation of the former is effected by roafting, and of the other by repeated fufion with borax. No peculiar ufe of this regulus is known.

*Regulus of arfenic* is obtained from *white arfenic* by fufion and fublimation. With a view to the firft of thefe, arfenic is mixed with equal parts of foap and pot-afh, and made to fufe by a fire quickly raifed; but the greateft part is loft in this manner. But if this mixture, purfuant to the fecond intention, be put into a retort, and urged with a red-heat, the regulus will be found fublimed in the neck of the retort. It is feparated from fulphur by fublimation in clofe veffels, though only when it is in a calcined ftate, by the addition of alkali or mercury.

* Tractatus Phyfico-chemico-medici, Page 1—16. [E]

† For the purpofe of extracting the regulus from the pure metallic manganefe, M. *Ilfemann* has very ingenioufly had recourfe to the compofition ufed for fmelting iron from its ores. Having mixed together half an ounce of powdered manganefe, a drachm and a half of fluor-fpar, half a drachm of lime, one drachm of charcoal, and half an ounce of decrepitated common falt, he expofed them in a clofe crucible to a very violent forge-fire, for the fpace of an hour and a half, and obtained a regulus of the colour of iron. [E]

Its

Its fusion with other metals, especially the refractory kinds, is promoted by fixed alkali; hence the arsenical neutral salt may be conveniently employed with this view. With respect to its union with iron, there is a circumstance worthy of observation, viz. that this latter metal is rendered of very easy fusion by it, and is no longer attracted by the magnet.

In order to obtain the *Regulus of Nickel*, the nickel is first deprived of its arsenic, by roasting it with powdered charcoal; and of cobalt and iron, according to *Bergman*, by liver of sulphur, by nitre, and by sublimation with sal ammoniac, though after all it is still attracted by the magnet: thus purified, it is fused with reducing fluxes. The pure regulus of nickel is said to combine with all the metals, excepting with mercury.

The *Regulus of Antimony* must also be first prepared first from the ordinary crude antimony, by a different mode of treatment; as this latter is nothing else than a purified ore of antimony. It may, indeed, be obtained from crude antimony without any farther preparation; but it is more advantageous in every case to use calcined antimony with this intention. Of all its different calces, antimony, calcined by itself, is the fittest for the purpose, because the sulphur, which is the greatest obstacle to its reduction, has been in the cheapest way expelled from it. This calx is to be mixed with half its quantity of stale fat kept for a length of time, resin, pitch, and the like, besides an eighth part of powdered charcoal; when the whole is to be put into a crucible, and the fat suffered to burn away. When the flame subsides, the quantity of two fingers depth of decrepitated common salt is to be added to the mixture; the crucible must be covered up, and the whole brought to fusion by a strong fire. In this manner the greatest quantity of regulus of antimony is obtained. This method was first taught by *Kunkel*. Instead of this calx, many other calces of antimony, such as crocus metallorum, powder of algaroth, as also glass of antimony, may be employed. All other preparations of crude antimony, with alkali, tartar and nitre, are inferior to this, with respect both to the produce and expence; because, in all these instances, a liver of sulphur is produced, which keeps the greatest part of the regulus back in the scoriæ. This is called the *simple regulus of antiony*, in order to distinguish it from the other compound kinds, which shall presently be mentioned. It is purified by being fused afresh with tartar. Its other appellations of *stellated* and *prickly* deserve not the least attention; these figures being merely accidental, and proceeding from the degree of its purity and of the heat employed.

The *Medicinal Regulus of Antimony* does notproperly deſerve the appellation of regulus, ſince it is nothing elſe than antimony ſomewhat changed, but ſtill whole and entire; and which has only been deprived of a ſmall portion of its ſulphur by the operation performed upon it. According to the moſt ancient formula five parts of antimony, one part of ſalt of tartar, and four of common ſalt, muſt be fuſed together, and after it is cold, the ſcoria muſt be ſtruck off from the maſs which is underneath, and this be triturated to a fine powder, and well waſhed with hot water. The common ſalt in this operation ſerves only for a covering flux; and hence it is a matter of indifference whether it be added or not. The ſmall portion of alkali extracts ſome ſulphur from the antimony, and conſequently alters the proportion of the two conſtituent parts, whence alſo its colour and effect are ſo much changed. For this reaſon the preparation does not look ſo black as crude antimony; but on the other hand it is ſo much the more active by the loſs of ſome of the ſulphur.

When various other metals, which bear a greater affinity to ſulphur, are fuſed with antimony, the metallic part is more perfectly ſeparated; but at the ſame time it will in every inſtance retain ſome of the precipitating metal; hence ariſe various *compound reguli of antimony*. Of theſe, the *martial regulus* of antimony is moſt generally uſed, which, according to the moſt ancient formula, viz. that of *Baſil Valentine*, is ſmelted out from two pounds of antimony, and one pound of iron, with half a pound of pot-aſh by a violent fire. *Beaumé* affirms, that in this proportion of the ingredients the regulus is very much contaminated with iron, and adviſes three parts of antimony to be taken to one of iron. This I myſelf alſo have found to be true; by this means a regulus is obtained, which indeed weighs leſs, but alſo contains leſs iron. Lead, tin, and copper, might likewiſe be employed with this view, but the regulus obtained with them cannot be uſed for the ſame purpoſe as the former. For the *regulus of metals*, two parts of the martial regulus of antimony are to be fuſed together with copper and tin, of each one part. To another compoſition conſiſting of martial regulus of antimony and copper, the ſurface of which has a reticular form, the name of *Vulcan's net* has been given, in alluſion to the well-known fable of *Ovid*.

The uſes to which *Zinc* is applied will be mentioned hereafter in its proper place. We ſhall only obſerve with regard to it here, that as it never unites with ſulphur, it may by means of this ſubſtance be diſengaged from every metal fuſed along with it.

*Bismuth* may be used for various compositions, which shall be mentioned farther on. We shall only speak of that extremely fusible metal which melts in boiling water, and which was first described by *Homberg*, and after him by *Rose*. It is prepared by melting together four parts of bismuth, two parts of lead, and the same quantity of tin. Fused with borax or alkali, it is said to beome a little more malleable. Equal parts of bismuth, lead, and tin, with a little quicksilver, yield a substance useful for injecting the blood-vessels; in certain cases, two parts of bismuth, one of tin, one of lead, and ten of mercury, compose the amalgam for making the *quicksilver globes*, with which the common people are fond of ornamenting their cielings. Bismuth, tin and antimony fused together in equal parts, form a mass fit for taking impressions of coins. Bismuth, tin, and mercury, taken in equal parts, produces the substances called *argentam musivum*.

*Mercury* must be purified by various means fordifferent purposes. This is effected partly by pressing it through soft leather, partly by triturating it with vinegar; but better still by distilling it out of a retort into a receiver, containing some water, though there is no certainty of obtaining it in the most perfect purity even in this method; for it has been found to carry over with it, in the distillation, partially at least, lead, tin and zinc. The surest method therefore is to separate the mercury from cinnabar, or rather from corrosive sublimate, with double its quantity of slaked lime, or fixed alkali. In the distillation with cinnabar pure iron filings may also be used, but the decompositlon of this latter substance in the moist way, by fixed alkali, is always imperfect*. Mercury is esteemed to be pure, when it looks bright, and runs rapidly on a plane surface in the form of small globules, without extending into an oblong form, and leaving a tail, as it were, behind it. According to *Morveau*, mercury has the least affinity to cobalt, a greater to iron, a greater still to regulus of antimony, and so on, rising in a regular series, to zinc, bismuth, lead, tin, silver and gold. According to these gradations, therefore, all the metals here mentioned may be amalgamated by means of different manipulations, of which something was known so early as in the times of *Pliny* and *Geber*.

No experiments are extant relative to the *Amalgamation of manganese, regulus of antimony* or *nickel*. *Regulus of arsenic* has been converted into a grey amalgam,

* The method of separating this metal from cinnabar practised in the time of *Theophrastus Eresius*, may be seen in his *Treatise upon Stones*, (translated from the Greek, by the late Sir *John Hill*). [A]

gam, by trituration for ſeveral hours. Pure *regulus of antimony* combines with great difficulty with mercury; but if it be put into heated mercury, and covered with water, a combination is in ſome meaſure effected. One part of melted *zinc* poured upon three of heated mercury, and afterwards triturated with it, forms a fluid amalgam. *Biſmuth* may alſo be united with boiling-hot mercury. *Purified platina made ductile*, and treated with boiling mercury, convinced Count *de Sickingen* of a combination having taken place. An *amalgam of iron*, according to M. *Vogel* of Brehna, is beſt obtained by digeſting an amalgam of zinc in a ſolution of martial vitriol*: and again by fuſing two parts of iron with three of antimony, ſo as to form a regulus, and then triturating this in an iron mortar with mercury and water†. *Lead* and *tin* are eaſily mixed in a ſtate of fuſion with four times their weight of heated mercury. An *amalgam of copper* is obtained by triturating together copper filings, mercury and vinegar. Beſides this, the cupreous powder precipitated by iron from blue vitriol, may be triturated with heated mercury, for the ſame purpoſe. Verdi-griſe, likewiſe, with common ſalt and vinegar containing iron, may be boiled up with mercury, and kept continually ſtirred, till the liquor becomes quite red. In this operation the copper is precipitated by the iron, and united with the mercury.

The *Amalgam of ſilver* is obtained by triturating fine filings of ſilver; or, which is ſtill better, ſilver precipitated from copper by iron, with eight or ten times its weight of mercury. An *Amalgam of gold* is very eaſily obtained by triturating fine filings of gold with mercury. All metals which unite in this manner with mercury, or, to ſpeak more properly, are diſſolved by mercury, exhibit particularly fine cryſtallizations‡. Upon a ſimilar principle too it is that the *Arbor Dianæ* is produced. To this end, four drachms of ſilver are to be diſſolved in pure aqua-fortis together with two of mercury, or elſe each of them may be diſſolved ſeparately; this ſolution is to be diluted with five ounces of diſtilled water, the mixture poured into a ſmall glaſs matras, into which ſix drachms of a ſoft amalgam of ſilver have been previouſly put, and the veſſel

* *Macquer's* Chem. Dict. (the German Edition, with additions by *Leonhardi*). Vol. V. p. 738. [A]

† A Metallurgico-Chemical Treatiſe on the Nature of Antimony. Jena, 1784, p. 133. [A]

‡ Vid. *Morveau*, Elemens de Chymie, T. III. p. 421—443. *Macquer*, Vol. I. p. 176. [A]

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ſet by in a quiet place, where it may be ſecure from all kind of agitation. In the ſpace of a few hours a metallic tree will ariſe from the amalgam, branching out into beautiful ramifications †. The whole of this reſult depends upon affinity. The diſſolved ſilver is ſeparated from the nitrous acid by the mercury, and in conſequence of the attraction which the particles of ſilver have to each other, is rather depoſited upon the ſilver that lies at the bottom of the veſſel, than any where elſe.

Of *Platina*, which is ſtill very ſcarce, no particular uſe is known, except the following: M. *Achard* had obſerved, that platina treated in a violent fire with arſenic and fixed alkali, was entirely fuſed, but that this metal, when all the arſenic had been expelled from it again by a long-continued red heat, recovered its former fuſibility: this led him to a method of making ſmall veſſels of platina, that were proof againſt fire ‡. Count *de Sickingen*, from ſix parts of platina, three of iron, and one of gold, obtained a metal which took an excellent poliſh, and was of ſuch a durable brightneſs, that it might be uſed for the mirrors of teleſcopes §. The general effect of platina is to make all metals that are mixed with it brittle. ‖

All *Iron* is either uſed as *caſt iron*, or *forged iron*, or for the *manufacturing of ſteel*. The firſt ſort, immediately after being ſmelted from its ores in the high-or blaſt-furnaces, is uſed as caſt-iron work, without any farther preparation. No caſt-iron will immediately bear to be hammered: it muſt therefore firſt be made fit for it §. This end is attained by making it *red-hot* and *hammering* it; by which means the *caſt-iron* is converted into *bar*-and *plate-iron*; or, to ſpeak in general terms, into *forged iron*. If it be afterwards fuſed again, it recovers its former brittleneſs. The abovementioned difference ſeems to depend upon this,

† Chem. Journ. Part II. pag. 3. 4. VI. p. 89—102. *Macquer's* Dict. of Chemiſtry. Vol. I.
‡ Chem. Annal. Vol. I. p. 3. & ſeq. § Experiments on Platina, *Manheim*, 1782. page 134. ‖ *Lewis's* Commercium Philoſophico-Technicum, page 524.

In this country, bar-iron is made in the following manner: Crude iron of the inferior kind is firſt granulated, and then waſhed with a lixivium of kelp, one ton of which is mixed with about a hundred and a half of iron, and ſome powdered lime. This mixture is divided into five or ſix large crucibles, which are afterwards covered, and then expoſed to the fire for about four hours in a large reverberatory furnace, called the *flouriſhing furnace*. When the crucibles are cool, the iron is ſeparated from the ſcoriæ; the weight of the iron obtained by this proceſs is generally about eighty pounds; thoſe particles of iron that remain in the ſcoriæ are afterwards melted in ſmaller crucibles, which are put into a furnace, called the *ball furnace*. [D]

that in fuſion, the parts attach themſelves to each other in a ſpecific regular form, in the manner of a cryſtallization, and in this ſtate muſt neceſſarily form a brittle body. By hammering the iron while it is red-hot, this regular form is deſtroyed again, and all the parts are extended in the form of threads, as it were, and intertwined with each other, by which means they neceſſarily cohere more ſtrongly with each other, and the iron acquires a greater degree of elaſticity and toughneſs. But as red-ſhort, cold-ſhort and malleable iron, are diſtinguiſhed from each other by different degrees of ductility, ſo again is *ſteel* diſtinguiſhed from the latter, by a ſtill higher degree of refinement*. This depends partly upon the *ſeparation of certain parts*, and partly upon the *reduction of others*, from which conſequently an actual metallization and *mutual approximation of the ſmalleſt metallic particles* of the body enſue. Steel is made: 1. from pure iron ores, that contain little or no ſulphur: 2. of bar-iron. In the firſt of theſe proceſſes the ſmelted iron is fuſed afreſh, cleared of ſlags and droſs, ſtretched

*. The difference between *Pig iron, malleable-iron* and *ſteel* appears to depend on the firſt of theſe ſubſtances containing a large portion of the vegetable principle combined with air, which in ſteel is without air, and in the beſt malleable iron, is as well as air, entirely wanting. In the firſt fuſion of the ores, or the converſion of them into pig-iron in the High-or Blaſt-furnaces, the iron receives the vegetable principle combined with air, or, in other words, the aerial acid from the burning coals; or this principle from the coals combining with the air already ſubſiſting in the ore, is converted into the abovementioned acid, which, together with the earth of the iron, forms martial aerocrate, by *Bergman*, improperly ſtiled, aerated iron. In the converſion of the pig-iron into ſteel, the air is diſſipated, and phlogiſton is abſorbed; ſo that (in perfect ſteel) the ferruginous earth is completely metallized, and there remains only the vegetable principle in union with the iron, forming, what is uſually called *Plumbago*. But when either of theſe is converted into *malleable iron*, both the vegetable principle and the air are ſeparated, and nothing remains but the pure metal ſaturated with phlogiſton. But the earth of iron has ſo ſtrong an attraction for air (at leaſt to a certain point) that the complete reduction of it is extremely difficult, and indeed is perhaps very ſeldom accompliſhed. Neither in all probability is ſteel often to be found without ſome ſmall portion of air, or pig-iron entirely without plumbago. Next to iron, perhaps zinc has the greateſt affinity with the vegetable principle; this metal in Mr. *Kirwan*'s experiments appearing to yield the greateſt quantity of fixed air: though the ſmall portion of this acid produced in the ſame way by copper and ſome other metals, give room to ſuſpect that theſe likewiſe attract the vegetable principle from the coals, when ſmelted from their reſpective ores, or from the reducing fluxes, when reduced from their calces. This idea, which the Editor communicated at the commencement of the year 1787, to his friend Profeſſor *Gadolin*, then in London, though it has not as yet been abſolutely confirmed by experiment, has ſince received an additional degree of probability from the ſuffrage of M. *de Fourcroy*, who in his Notes to the French Tranſlation of Mr. *Kirwan*'s *Eſſay*, has advanced the ſame opinion. [E]

under the hammer and wrought, a procefs that confifts in forging the iron into bars, and cutting thefe into fmaller bars, welding them together by fours or eights, then forging them again into thin bars, and repeating this operation feveral times more if requifite. In this procefs, one half of the iron generally difappears. It may be prepared from bar-iron, either by fufion or cementation. The former is effected by plunging the iron bars into melted iron, and keeping them there for fome time. In the other method it is ftratified with different combuftible matters, fuch as the bones, horns and hoofs of animals, wood-foot, &c. and kept in a ftrong red heat, in covered veffels, for the fpace of ten or twelve hours, and at length quenched in cold water. This is called *Cemented Iron.* By this means it is changed into fteel, to the depth of a few lines only from its furface. The whole of the procefs for manufacturing fteel feems to confift in this, that a fmall portion of fulphur is ftill intimately united with the iron; now when the acid of this be expelled by fire, a purpofe anfwered by combuftible matters, which at the fame time ferve to reduce the portion of iron mineralized by it, it becomes more compact, harder and heavier. On this account fteel does not throw out fparks fo much in the fire, nor ruft fo eafily as mere iron does. The whole fcope of the operation is to expel fomething from the iron, and to produce a more intimate union of the ferruginous parts. Steel therefore is iron, the metallic property of which is carried to the higheft pitch poffible*. That which is prepared by fufion is better than that which is obtained by cementation. The degree of hardnefs in it depends upon the quicknefs with which it is quenched.

The famous *Damafcus Steel* is prepared by art, in the following manner: Eight plates of fteel are forged, a foot long, an inch broad, and a line thick, five plates of foft iron, and four others of brittle iron, are then made of the fame thicknefs, length and breadth, as the former, which are put together in the following manner: Firft, a plate of foft iron is laid down, upon this one of fteel, on this one of brittle iron, then another of fteel, upon this again another of foft iron, upon this one of fteel, and fo on to the feventeenth plate, which again is of foft iron. This bundle is then taken up and carried to the fire by means of a pair of crooked tongs, and welded firmly together, with a moderate red heat only; ftretched in the form of a fquare, and fomewhat planifhed. It is next brought to a white heat, and, one end of it being put into a ftout vice, and the other laid hold of with a ftrong pair of tongs, twifted round as hard as poffible, fo as to take the form of a fcrew; upon this it is planifhed, hammered down to the breadth of eight or nine lines, and from three to four in thicknefs,

* For Note, Vid. Appendix.

and cut into two equal parts, that serve as a case or cover. A plate of Styrian steel is then cut, of the thickness of two lines, and of a length and breadth equal to that of the case; this steel ought however to be selected out with great care, so that it shall be pure and good. This plate of steel is now put between the two covers, and in this situation it is carried to the fire with a pair of tongs, and stretched to such thickness as the instrument that is to be made of it requires. All this having been literally observed, you will have the true Damascus ware, the steel-plate in the middle of which will compose the edge of the instrument, which, in consequence of a good hardening being given to it, will acquire an equable hardness. Now as the sheath or covering on each side consists of seventeen plates, which united, form thirty-four plates intertwined with each other; they will impart to the instrument a toughness and durability, so as to prevent it from being broken by the greatest force. This artificial steel is distinguishable from the native by its veins being more easily seen, as well as by the circumstance that none of them appear on the edge of the instrument, which on the contrary are every where visible in native steel.

*Lead* in its metallic state is most commonly used for the purpose of casting bullets and shot. Besides this it is cast into thick leaden plates, which are afterwards extended into thinner plates by means of rollers. When alloyed with copper, brass and antimony, it constitutes the *Metal used for Printers Types*. With regulus of antimony as also with bismuth in different proportions, various mixtures might be made, which might serve for many purposes in which ductility or toughness are not absolutely requisite. Thus from ten ounces of lead, six ounces of bismuth and four drachms of regulus of antimony, a very hard metal is obtained, of a fine and close grain, which looks as white as silver.

I pass over the mechanical uses of *tin* for kitchen furniture of various kinds, and its great extension when beaten out to *tinfoil*, and the still thinner *mock-silver leaf*. In the universal use that is made of it, particular attention should be paid to its arsenical residuum, which, according to *Marggraf*, amounts to one eighth part in the Malacca tin, and to still more in other sorts.* For common use, when it is called pewter, it is alloyed with a third or an eighth part of lead, a circumstance in which however the pewterers frequently impose upon

* It does not by any means follow from *Marggraf*'s experiments, that there is arsenic in all tin. And indeed *Marggraf*'s observation is refuted in the 'Recherces Chymiques sur l'Etain,' par Messrs. *Bayen* et *Charlard*. Paris, 1784. [A]

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the purchaser; as hitherto no certain method has been discovered, by which the proportion of these two metals when melted together can be ascertained; as indeed, in general, the way to separate them perfectly is entirely as yet totally unknown. For the purpose of hardening the pure or English tin, as it is called, and that at the same time the whiteness of the colour may not suffer by it, regulus of antimony, zinc, or bismuth, are fused along with it in a small proportion, of which mixtures, the tin alloyed with zinc possesses the greatest ductility. By melting together tin, iron and arsenic, a white metal is obtained, that has the appearance of silver. Two parts of tin and one of bismuth, form a peculiar mixture, which has obtained the name of *Tutenag*, an appellation, that otherwise belongs to zinc only. From three parts of tin with one of copper, and a little arsenic, mixed with black flux, a *hard metal of a steel-colour* is obtained, which is fit for burning mirrors. The composition, called in Germany *Hard Pewter*, is prepared with twelve ounces of tin, one ounce of regulus of antimony, and two drachms of copper. For some years past, vessels of various kinds, if I am rightly informed, have been made at Neuwied, the composition of which is said to be iron and tin, melted together.†

*Copper* serves for a still greater number of useful compositions, many of which are among the inventions of antient date. It was the basis of the *Corinthian Brass*, so famous in ancient times, of which *Pliny* mentions three different sorts, which, according to the account given of them, must have very much resembled our brass and tombac. *Brass*, the name of which occurs so early as in *Aristotle*, under the appellation of *Aurichalcum*, is thus prepared in the

† In Sweden they have a method of covering copper with a very thin coating of tin, by boiling up the former of these metals along with the latter in a solution of tartar, or of tartar' alum and salt, in water. It is likewise used here by the pinmakers. This apparent irregularity in the order of elective attractions (according to which copper is precipitated from its solution in acids by tin) Professor *Gadolin* has endeavoured to explain by the attraction which copper has to metallic tin, joined with that which the dissolved particles of this latter metal exert towards the *calcining matter* (or air) contained in the particles of the same metal that are nearest to the copper; in consequence of which these last particles of the tin are deposited upon the surface of the copper, while the rest, which compose the most considerable part, undergo a greater degree of calcination. It is to be observed at the same time, that the tin employed for this purpose, must be (at least part of it) in a metallic state. [E]

great:

great: Copper, roasted calamine, or roasted blende and cadmia formacum, are exposed to the fire in strata, and melted down together with powdered charcoal; in which operation the zinc contained in the calamine being reduced and united with the melted copper, gives it a yellow colour, and proportionably augments its weight, without taking from its ductility. *Prince's metal*, invented by a Palatine Prince of the name of *Rupert*, who was an English Admiral, and died in the year 1682, is a kind of brass, in the composition of which copper and zinc are fused together in different proportions, and in fact, zinc is always used in greater quantity for this purpose than any other composition. It may be prepared either with three parts of copper and one of zinc, or eight parts of brass and one of zinc. The copper is first covered with a thick stratum of powdered charcoal and fused, then the zinc is added, stirred in, and poured out quickly. *Pinchbeck*, on the other hand, is a metal similar to this, but has less zinc in its composition than brass has. One ounce of brass fused with one and a half, or two ounces of copper, under a covering of powdered charcoal, yields a ductile metal of a golden colour, which derives its appellation from an Englishman of this name. The *Manheim gold* or *Similor*, is a kind of pinchbeck, that has a colour very like gold, and of which a manufactory was established at Manheim, in the year 1760, by M. *Macher*. *Tombac* is distinguished from the preceding sorts by a red hue; and consequently requires the least quantity of zinc. As an instance, may serve the composition of three ounces and a half of copper to one ounce and a half of brass; to which likewise may be added fifteen grains of pure tin. The name of this metal immortalizes the name of the artist who first prepared it in England. *Marggraf*, from twelve parts of copper and one of zinc, obtained a fine and soft kind of tombac; as likewise from sixteen parts of copper, one of tin, and one of zinc. With respect to the coarser of these compositions, *Gun metal* is cast from 100 lb. of copper and twelve of tin, either with or without the addition of a small quantity of brass. *Bell-metal* is composed of 100 parts of copper mixed with from twenty to twenty-five parts of tin, or, instead of the latter, with lead and a trifling admixture of brass. To this head also may be referred the metal described by *Gerhard*, consisting of copper and iron. Fluor-spar and lime an ounce and a half of each are mixed with one drachm of iron filings, with this two ounces of copper are stratified in a crucible, and exposed for the space of an hour, to a very strong heat. After it was beaten to pieces, $1\frac{7}{8}$ of an ounce of a metal was found, which had a yellowish cast, was very malleable, and easily filed, and was attracted by the

 magnet*.

magnet*. Divers antient weapons, found in the earth, are faid, upon being analyzed, to have confifted of copper, iron and zinc. Thofe that were dug up in this country fome years ago, and, to all appearance, confifted of three different materials, contained, according to the affay I made of them, neither iron nor zinc, but confifted merely of copper and tin compounded with each other in different proportions†. The difference of the *Japanefe copper* from the common is faid to depend on a portion of lead contained in the former. *White copper* is prepared by fufing copper with arfenic, in which operation the arfenical neutral falt particularly promotes the incorporation of the arfenic with the copper. With a fimilar view, one part of arfenic is fufed with from four to five of copper; but if from eight to twelve parts of copper be taken, a more or lefs yellow or reddifh-yellow copper is obtained. A peculiar Chinefe metal, which bears the name of *Pack-fong*, is faid to confift of copper, nickel and zinc. For this purpofe the metal of a ferruginous copper ore, in Canton, is firft mixed with zinc. In the crude copper ore containing nickel, the nickel is found with the copper in the proportion of five or fix to thirteen or fourteen. The addition of zinc is not always the fame, and amounted, according to *Engeftrom*, to $\frac{7}{16}$‡. According to *Bochart*, the *flame-coloured copper* (aes pyropum) of the antients, confifted of four parts of copper and one of gold.

*Silver*, in its pure ftate, being judged too foft for the purpofes of common ufe, is ufually *alloyed*, as it is called, or mixed with copper; as well for manufacturing into plate, as for coinage. In all *coins*, two points are principally to be confidered; the alloy, and the weight; the proper mixture of the firft afcertaining the finenefs of the filver to be coined, the latter regards the precife weight of each individual piece; and thefe together determine the *Standard* of current money, according to the peculiar laws of different countries. Thus on a mark, or eight ounces of filver dollars, the fine filver is only feven ounces and four affay grains, or $7\frac{4}{12}$ with $\frac{8}{12}$ of a grain alloy; and the weight of each dollar is one ounce. Thefe conftitute the ftandard; and coins of fimilar denominations muft be in like proportions. On the inferior fpecies of coin, large deductions are

* *Gerhard's* Chemical Obfervations on the Melioration of Iron by Copper, in *Sellen's* New Contributions to Natural Philofophy and Phyfick. Vol. III, page 202. [A]

† Acta Acad. Elector. Moguntinæ ad Ann. 1777.

‡ *Engeftrom's* Defcription of the Pack fong, in the Neuefte Entdeck: en der Chemie. Vol. III, page 178—181.

often

often made, both from the finenefs and weight, as a charge or tax to defray the expence of coinage, under the name of *Remedy*; a circumftance which is particularly neceffary to be underftood, previous to the bufinefs of affaying them*.

*Gold*, on the fame principle, is ufually alloyed with filver or copper, or both. In coins of gold, all the circumftances are to be obferved the fame as in refpect of filver†. In manufactures of gold, the workmen frequently alter the colour of the metal by certain admixtures, not yet generally known. The green colour, fometimes given to gold, is faid to be partly derived from zinc‡.

* In Great Britain, all Gold and Silver is weighed by *Troy weight*: the unit, or pound, being divided into twelve ounces, the ounces into twenty penny-weights, and each penny-weight into twenty-four grains. The finenefs of Britifh filver coin is $\frac{111}{120}$ parts of pure filver, with $\frac{7}{120}$ parts of alloy; and one troy pound of this mixture is cut into 62 fhillings; and other coins in like proportion. No charge or deduction is made for coinage; the expence being born by the State. All filver money fhould therefore be duly of the above ftandard. The term *Remedy*, as ufed in the Britifh Mints, has the natural fignification, and means only a faving claufe, (for fallibility of workmanfhip) of a few troy grains under or over the precife ftandard, at which thefe coins may pafs for good. The plate, of all forts, in Great Britain, as well of gold as of filver, is all to be of the fame degree of finenefs as the coins refpectively.

† The Standard of the Britifh gold coin, is, by law, for every troy pound weight to contain $\frac{11}{12}$ of pure gold, with one $\frac{1}{12}$ of alloy; and this mixture to be cut into 44 $\frac{1}{2}$-guineas, or other pieces of like nominal value; without any deduction.

‡ The allaying of gold for manufactures, with uncertain mixture, is however to be ufed cautioufly; as the precious metal is thereby often rendered brittle, and unmanufacturable, when the caufe is not eafily to be affigned. It is an old opinion, handed down through moft writers on metallurgy, that tin, in the minuteft portion, or even the fumes of tin, would be fufficient to deftroy the ductility of large maffes of gold. But Mr. *Alchorne*, Affay-mafter of the Mint in the Tower of London, has clearly fhewn, from a chain of experiments, printed in the *Philos. Trans.* 1785, and fince extracted in the *Journal de Phyfique*, Sept. 1785, that this doctrine is merely a vulgar error. Mr. *Alchorne*, having an opportunity, which few other Chemifts will have, of experimenting on large maffes of fine gold; made trial of mixing twelve ounces in fufion with tin, in different proportions, from 60 troy grains, to 240. As alfo of keeping melted gold furrounded with the fumes of tin; and afterwards of alloying thefe mixtures with different quantities of copper and filver; but in all thefe cafes, he found the refult of his mixture ftill manufacturable; capable of being flattened by hammers, or between fteel rollers; of being ftamped into coin, wrought into trinkets, or even drawn into fine wire. On proceeding farther, however, and melting an ounce of tin with twelve ounces of fine gold, the compound loft its colour and ductility. Mr. Alchorne acknowledges, that the peculiar brilliancy and texture of fine gold was apparently debafed by the admixture of tin, in the proportion of half an ounce to twelve ounces, but that the refult had not the leaft appearance of what every workman knows by the name of brittlenefs; and which he, with good reafon, fuppofes to be moft commonly the effect of arfenic. [E]

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We shall now proceed to make mention of the *Calciform Preparations of Metals* which are effected, some by *fire* only, some by *saline substances*, and some by means of *sulphur*. In these operations, the more they are deprived of their phlogiston, the nearer they approach to the state of a calx *.

When one part of *Manganese* mixed with three parts of nitre is kept in a crucible in the fire, till the nitre is destroyed, and the whole mixture becomes a thick, grumous mass, it is called the *Mineral Chameleon.* If a small quantity of this be poured into a glass of spring water, the finest change of colours is seen in the quickest succession; a most beautiful green colour appearing immediately at first, and almost instantaneously changing to a violet, and lastly to a red. A similar phenomenon takes place also in the fusion of it with alkali. *Cobalt* is already by nature in a calcined state, but when it has been put by art into a metallic state, it is easily calcined by fire alone. This is also effected in another way, by dissolving it in acids, and precipitating it with an alkali. *Arsenic* is in like manner acquired under the form of white arsenic, into which state also the regulus of arsenic may easily be brought by sublimation. *Pure nickel* by calcination in fire, forms a green calx, but if it contains iron, it contracts a rusty colour. The same effect is produced upon it likewise by sal ammoniac. *Antimony*, as well as its regulus, forms a grey calx, merely on the application of a gentle fire, and being kept continually stirred; when the sulphur is expelled from the former, and the reguline part also is deprived of the greatest portion of its phlogiston. When a more intense heat is applied in a proper apparatus, both are sublimed and carried aloft in *flowers*, which are yellow or reddish from the former, but white from the latter. By means of salts, they both yield, as well in the dry way as humid, a great number of calces of different appellations, which calces have obtained a place among medical preparations; although their number has been much diminished in latter times.

The *Liver of Antimony* (Hepar Antimonii) is prepared from crude antimony, by mixing eight parts of antimony with seven or even an equal part of nitre, and detonating them by means of a piece of ignited charcoal in a metal mortar; or by fusing two parts of the former together with one of pot-ash. But if one or the other

* Metals are calcined by absorbing air, at the same time that they part with their phlogiston. This they do either by attracting the pure air of the atmosphere, when their attaaction to phlogiston is diminished by the interposition of heat, (for which purpose more or less heat is necessary, according to the nature of the metal;) or else by decomposing other substances containing air, particularly water and acids, and that by a double elective attraction. [E]

of these compound masses be elixated with water, so that the saline parts may be separated from it again, the residual brownish-red powder acquires the appellation of *Saffron of metals* (Crocus Metallorum, Crocus Antimonii). On the other hand, if one part of crude antimony, reduced to powder, be mixed with two and a half or three parts of well dried nitre, and put by small portions at a time into a red-hot crucible, a thick liquid matter of a white colour is obtained, which after being kept in fusion for a quarter of an hour, is again taken out of the crucible with a spatula, and suffered to cool upon a plate of metal. It exhibits a nitrated calx of antimony, under the name of *unwashed diaphoretic antimony* (antimonium diaphoreticum non ablutum, or fondant de Routrou). In this operation, which consists in a violent detonation, by which the sulphur of the antimony and the phlogiston of the reguline part are destroyed, some half destroyed, antimonial particles are also carried aloft with the rest, which readily attach themselves to the upper edge of the crucible, in the form of a brownish crust. These possess an emetic quality, and must therefore, now and then, during the operation, be struck off, and mixed with the fluid mass; or they must be prevented from adhering at all, by surrounding the crucible with coals quite up to the brim, in consequence of the heat arising from which, this adhesion does not take place, or the particles that have already attached themselves may be easily struck off again. If this operation be performed in a red-hot tubulated retort, the antimonial flowers, which otherwise escape in the open air, may at the same time be collected. From the mass, melted in either of these ways, is obtained *diaphoretic antimony*, by edulcorating it with a large quantity of water, till there is not the least saline taste any longer to be perceived; when the washed powder may be passed through a fine hair sieve and dried upon a filter. The preparation of it is to be found in the works of *Basil Valentine*, who first described it. It consists merely of the metallic part of antimony, completely calcined by nitre, the nitre having destroyed the sulphur as well as the phlogiston of the regulus. The repeated fusion of it, with a fresh addition of nitre, in order to prepare the *poudre de la Chevalleray*, is quite a useless operation. In the edulcortation of the fused mass above-mentioned, part of the calcined antimony is dissolved in the water; hence, if diluted vitriolic or any other acid be poured into it, after it has been decanted from the calx, a very light white powder is precipitated, the amount of which however, when weighed, is very trifling. It has had the name of *materia perlata* given it; probably because its nature was not at that time better known. It was afterwards, with greater propriety, called *magistery* of *diaphoretic*

*diaphoretic antimony*. This precipitate is obtained in abundance, by boiling the fused mass in water. One part of antimony fused with an equal quantity of iron filings, and the mass, after being poured out, mixed with four parts of nitre, and treated in every respect as in the process for making diaphoretic antimony, produces the *martial diaphoretic antimony*. Another powder prepared from antimony is the *mercurius vitæ*, or *powder of algaroth*. This is obtained by precipitating butter of antimony by diluting it in a large quantity of water, and afterwards edulcorating the powder likewise with water. According to *Scheele* it is also produced, by digesting one pound of liver of antimony for the space of a a day with a mixture of three pounds of water, one pound of oil of vitriol, and the same quantity of common salt: should part of it still remain undissolved, a third part or half of this mixture, after the liquor first impregnated is decanted, may be poured upon it, with which it may be digested. The whole of the clear lixivium obtained is finally to be precipitated with hot water, and the precipitate farther edulcorated. The precipitate is a violent emetic, as it is, properly speaking, nothing else than a calcined regulus of antimony, from which all the phlogiston is not yet expelled, since the marine acid is not able to disengage it in the preceding combination. But when, upon one part of butter of antimony, or which is still better, upon the powder of algaroth, precipitated from it, two parts of nitrous acid are poured and distilled from it to dryness, the residuum urged with a red-heat, and finally edulcorated with water, the produce is *mineral bezoar* (bezoardicum minerale) which does not differ in its nature from diaphoretic antimony*. The nitrous acid, in this operation, expels both the phlogiston still adhering to the calx, and at the same time the marine acid, in consequence of which the calx loses its former activity. Other preparations of antimony, which are no longer in use, we shall pass over, to avoid prolixity.

Pure *Regulus of Antimony* is used for the following preparations: For the *Ceruss of Antimony*, with one part of pulverized regulus of antimony, are mixed three of nitre likewise reduced to powder, of which however one part or at most one and a half are sufficient; the mixture is then fused in a crucible and elixated. By this means is obtained a perfectly calcined regulus of antimony, which is acquired also equally as good in the preparation of diaphoretic antimony. Consequently both are, in fact, exactly the same thing with the bezoar mineral, and materia perlata mentioned before. From one part of the pulverized mar-

* In fact, they seem both to be mere calces of antimony, i. e. antimony deprived of the greater part of its phlogistion, and combined with pure air. [E]

tial regulus of antimony mixed with two or three parts of nitre, and fused in a crucible, after previous edulcoration, is separated the *bezoardicum martiale* or *Stomachicum Poterii.* The *Diaphoreticum Joviale*, otherwise called *Antihecticum Poterii*, is obtained, by fusing equal parts of the martial regulus of antimony and tin together, and after pouring the mass out and reducing it to powder, fusing it afresh with three parts of nitre, and elixating it. The process is longer and more expensive, though not better, when regulus of tin mixed with three times its quantity of corrosive sublimate is distilled over in the form of a metallic butter, and from this double the quantity of nitrous acid is drawn off several times, by distillation, till the retort becomes red-hot; after which the residuum is edulcorated.

*Zinc* is easily fused by mere fire, but as soon as it is heated so as to be red-hot, it takes fire, and at the same time emits a dense vapor, which attaches itself to every thing within its reach, in the form of white cobwebs. These are the *flowers of zinc*, which on account of their extraordinary levity, and at the same time, by an alchemistical conceit, have been called *Philosophical Wool*. All that is produced from zinc in this manner, forms a very inconsiderable mass, and it would be attended with great trouble and expence to get one pound only of it: not to mention that this is nothing more than a mere *calx of zinc*, in no respect better than that which remains in the crucible after the combustion. In order therefore to prepare the flowers of zinc in a more advantageous manner, a large crucible is laid in a wind-furnace among the coals, quite slanting upon its side, so that the mouth of it shall be directed towards the operator, and the whole is covered as much as possible with coals. Upon this several pounds of zinc are put into it and suffered to fuse, and the impurities are taken off from the top with a spatula, if after the fusion any such should appear. Now, as soon as the zinc begins to burn, the flowers will immediately attach themselves to the uppermost part of the crucible, but at the same time too, a white porous substance will lie upon the melted zinc, which covers up its surface and prevents the farther combustion of the metal. This is now to be carefully taken off from the surface of the metal, so that no melted zinc may mix with it, and it is left for some time in the fore-part of the crucible, till it is thoroughly calcined; after which it is taken out of the crucible, and put upon a plate of metal. But as soon as the light, flaky substance is removed, the melted zinc is immediately inflamed again, by which its surface is also directly covered afresh with a light, porous matter; this is likewise suffered to burn out, and put along with the former part: and in this manner the process is continued,

till

till at last the whole of the zinc is changed into a light, flaky calx. A certain empyric at Amsterdam, of the name of *Ludemann*, gave the flowers of zinc, under the appellation of *luna fixa*, as a nostrum. But *Gaubius* discovered the nature of the powder by its growing yellow when heated red-hot, and becoming white again when cool, which is a certain criterion of the calx of zinc. When a similar calx on the occasion of an ore containing zinc being smelted for some other metal, settles in the chimneys, it bears the name of *Nihilum album*; but that part which on the same occasion attaches itself to the seat of the zinc, in the furnace itself, constitutes the *Cadmia fornacum*; and that, which in the fusion of brass, is deposited in the furnace just over the melted mass, is called *Tutty*. All these three products therefore consist of a more or less pure calx of zinc. As to the preparations of salts, *diaphoretic calx of zinc* (zincum diaphoreticum), is prepared by putting zinc, mixed with two or three times its weight of nitre, into a red-hot crucible, fusing, edulcorating and drying it. The *Magistery of Zinc* is obtained by dissolving zinc in an acid, diluting the solution, and precipitating the metal with fixed alkali.

*Bismuth* calcines in the fire like lead, to a yellow calx, which also in a more ntense heat fuses to a yellow glass, that may be used for the separation of the base metals from gold and silver, with the same good effect as glass of lead. Most part of it may also be sublimed in the form of vapors, in an open fire. With twice its weight of nitre, in a proper apparatus, it is sublimed in the form of *flowers*. *Spanish white*, *King's white* or *Precipitate of Bismuth* is obtained from the solution of bismuth in nitrous acid, by precipitating it with a larger quantity of water; but what in this operation is still retained in the solution, may be entirely precipitated by means of fixed alkali. It is best to precipitate it with this at first, and after all to edulcorate the precipitate thoroughly.

The change of *Mercury*, merely by fire, to a red mass called *Mercurius calcinatus per se*, is a fact which at a very early period was known to *Geber*. This preparation undoubtedly derives its origin from a notion entertained either by him or his predecessors, that they could change mercury into silver by a continued fire. The main point in this operation depends upon the following particulars: 1. That at least half or a whole pound of mercury be used for it: 2. that it be poured into a phial with a neck four feet long, the bottom of which must be covered all over with mercury: 3. a piece of paper only must be tied over the orifice, to prevent dust or other impurities from falling into it: now 4. the principal point of all depends upon the

the degree of heat; this muſt be ſo intenſe as continually to raiſe the mercury in the phial to the height of two feet, in the form of vapors, from whence it falls back again into the phial: and laſtly, 5. this degree of heat muſt be continued without any alteration day and night, for the ſpace of ſix months, by which means the mercury is changed into a bright-red powder. The whole of this operation conſequently conſiſts in a circulatory diſtillation, continued for the ſpace of ſix months, in which the fluid mercury, by the matter of fire continually penetrating it, is in ſuch a manner divided into its ſmalleſt particles, that by this matter, which is alſo combined with them, they loſe their former coheſion, and acquire a pulverulent form. Sometimes too, ſome veſtiges of this alteration are ſeen in the diſtillation of mercury. This exceedingly tedious and expenſive operation may be ſhortened in the following manner, and finiſhed in two days. With this view a quantity of mercury ad libitum is diſſolved in nitrous acid, and the ſolution diſtilled to dryneſs, in a retort placed in ſand, on which occaſion the nitrous acid comes over in the form of red vapors, and a white maſs remains behind. Upon this the fire is increaſed, and continued till the maſs acquires a fine crimſon colour*. This is the *red precipitate of mercury* uſed in the ſhops; the firſt mention of which preparation occurs in *Baſil Valentine*. It was formerly thought that it derived its corroſive property from ſome nitrous acid that ſtill remained combined with it, but according to my own experience and repeated obſervations

* M. *Dollfuſs*, after various attempts to diſcover the beſt mode of preparing the red calx of mercury, found the following method moſt ſucceſsful: Four pounds of quickſilver are to be diſſolved in a ſufficient quantity of nitrous acid; and the acid drawn off by diſtillation: when the reſiduum is to be calcined, till the receiver is quite clear and free from vapor. This is a ſign that the mercury is totally deprived of its acid; and juſt at that point of time when the vapors in the receiver begins to loſe their red colour, dephlogiſticated air paſſes over into it: when the calcination is immediately to be put an end to. Mercury thus calcined will not diſcover the leaſt trace of nitrous acid, and is increaſed in its weight $\frac{1}{10}$. There is found, attached to the upper part of the retort, a kind of ſublimate, which is about $\frac{1}{16}$ of the whole weight of the quickſilver. This ſublimate is of a red colour, and contains about $\frac{1}{6}$ of its weight of corroſive ſublimate. The other is merely calcined mercury, which was ſublimed by the vapors of the nitrous acid. This ſublimate, which conſiſts of $\frac{3}{16}$ of corroſive mixed with a little mild ſublimate, and $\frac{13}{16}$ of calcined mercury mixed with a little nitrous vapor, M. *Dollfuſs* uſed for the purpoſe of preparing corroſive ſublimate, as follows: he mixed four ounces of it with ſix of decrepitated common ſalt, and three of vitriol calcined to redneſs, which mixture being expoſed to a ſand-heat, in a retort, produced very good corroſive ſublimate. Vid. *Dollfuſs Erfahrungen*, &c. p. 2. [E]

made

made by others, there is not the leaſt particle of this in it. The mercury is divided into its ſmalleſt molecules by the nitrous acid, and then forſaken by it in this ſtate. As this eſcapes, the matter of fire penetrates into the mercury from the outſide of the retort, by which it is kept in its divided ſtate; and at the ſame time its corroſiveneſs, colour, and additional weight is cauſed. The nitrous acid therefore here is a preparative, by which the mercury is rendered fit, that the matter of fire*, in the ſpace of a few hours, may be combined with it in its divided ſtate, an effect, to produce which otherwiſe, five or ſix months, and ſometimes more, are requiſite. Both preparations conſequently are in reality perfectly alike. They are both indeed called red calces of mercury; but they are not ſo in the ſtrict ſenſe of the word; becauſe the mercury in this operation does not loſe its phlogiſton, which, as a true metallic calx, it ought to do; for they may both be converted again into real quickſilver, without the addition of phlogiſton, by diſtilling them over with a fire ſufficiently fierce to make the retort red-hot. *Paracelſus* and his followers uſed the latter of theſe preparations as an internal remedy, and on the ſuppoſition that the corroſive property diſcovered in it was derived from the nitrous acid ſtill adhering to it, imagined that this corroſiveneſs might be mitigated by ſpi it of wine. They therefore covered it with this fluid, which they ſuffered to burn off from it ſeveral times, and called the powder *Arcanum corallinum*. But their labour was

* There is no occaſion to ſuppoſe the combination of the matter of fire from the coals with the ſubſtance of the mercury. In both preparations it is the air which combines with the metal, and effects the change abovementioned. It is true, the phlogiſton muſt at the ſame time be carried off; and this office is performed in the caſe of the red precipitate by the nitrous acid, the baſe of which uniting with the phlogiſton of the metal, flies off in the form of nitrous air, and leaves its other component part, viz. the air, behind in combination with the mercurial earth. In the other operation, viz. of making calcined mercury, the air of the atmoſphere unites with the baſe of the metal without any intermedium: but what carries off the phlogiſton in this caſe, has not as yet been determined. That it is not a combuſtion is certain; as no light has been ſeen generated in the operation. It appears to me, however, that this ſubtle principle muſt neceſſarily make its eſcape in the form of inflammable air, by means of a double decompoſition, and by uniting with the hydrophloge of the water always contained in the atmoſphere. In ſhort, the calcination is, in all probability, the ſame in every reſpect with that of other metals.—Both theſe preparations may be reduced again to the metallic ſtate, by being heated in contact with ignited glaſs or any other ignited ſubſtance, which, as in the uſe of glaſs retorts, giving out no other matter than the light and heat of the fire tranſmitted through them, it is plain that the reduction is effected merely by a ſingle decompoſition, and conſequently that the attraction of mercury to phlogiſton is greater than it is to air. [E]

loſt.

loſt. To others the idea occurred of triturating it for a certain time with a ſolution of ſalt of tartar, and then waſhing the ſalt out from it again with water; when they gave it the name of *Pulvis principis*, or *Princes powder*. Theſe however were as far from attaining their end as the others had been; as the corroſiveneſs of the preparation did not proceed from any acid adhering to it. A calx ſimilar to this may be obtained by keeping the white precipitate of mercury and mercurius dulcis, for a certain ſpace of time in ſuch a degree of heat as they cannot be ſublimed by. *Kunkel's red ſublimate of Mercury* compoſed of quickſilver, nitre and vitriol, agrees exactly with this in the main point. Already before *Kunkel's* time it was prepared by *Iſaac Holland*. In *Cadet's* opinion, this calx is produced when the globules of mercury are ſublimed to the roof of the veſſel, and remaining there, are by degrees calcined by the heat, and thus form ſmall red cryſtals *.

Beſides theſe preparations mercury is, in divers other ways, brought into various calciform ſtates by mere ſaline inter-mediums, which even externally are diſcriminated from each other by different colours, and are as different in their effects.

Hither too is to be referred the *White precipitate of Mercury:* To obtain which one ounce of mercury, for example, is to be diſſolved in ten drachms of ſtrong nitrous acid, or in as much, as, according to its ſtrength, is neceſſary for the purpoſe. The ſolution being ſufficiently diluted with water, two, three, or even four drachms of ſal ammoniac diſſolved in eight ounces of water, are added to it; after which the mercury is carefully precipitated with the ſolution of fixed alkali, ſo that there may be no redundance of the latter, and the precipitate is well waſhed with water. Excluſively of the above method this preparátion may alſo be obtained by diſſolving, in imitation of *Lemeri*, equal parts of corróſive ſublimate and ſal ammoniac in boiling water, filtering this ſolution, and precipitating it with a ſolution of fixed alkali: in both inſtances the mercury is precipitated of a white colour, by the intervention of the volatile alkaline ſalt; as this, in conſequence of its greater affinity, attracts the matter of fire from the fixed alkali, and thus prevents its combining with the precipitating mercury. When mercury, diſſolved in nitrous acid, is precipitated by fixed alkali, or lime water, a *mer-*

* The principal circumſtance to be attended to for obtaining the red ſublimate of mercury ſtill remains to be noticed, which is that the ſublimation muſt be carried on in a veſſel, into which the air may have acceſs; for example, in a retort without any receiver luted to it, or in an open phial. For otherwiſe the mercury will come over in its metallic ſtate. [A]

*curial* precipitate is obtained, of a browniſh red colour. But if the mercury be put into a retort with equal parts of vitriolic acid and ſubjected to an intenſe heat, till the mercury in it is reduced to a dry white maſs, and this is afterwards elixated with water, the mercury, now corroded to a powder, acquires a brimſtone-yellow hue, and is converted into *turpith mineral* (turpethum minerale). The water uſed for this ſolution ſtill contains a portion of mercury diſſolved in the vitriolic acid. A precipitate exactly ſimilar to this is obtained, by mixing a ſolution of mercury in nitrous acid with vitriolic acid, or elſe with a ſolution of vitriolated tartar, or of Glauber's ſalt, or of Glauber's ſal ammoniac. The ſolution of mercury may be precipitated beſides of a *clear orange colour* with pure mineral alkali; *roſe colour* with urine; *vermilion red* with Beguin's ſpirit; *blue* with Meyer's extract of Berlin blue; and *black* with a ſolution of liver of ſulphur. In more ancient times a *green precipitate of mercury* was alſo uſed, which, on account of its effects, was called *lacerta viridis*. For this, eight parts of mercury and one of copper were diſſolved in nitrous acid ſeparately, the ſolutions mixed together, and the acid drawn off from this mixture to dryneſs, and at laſt with an intenſe heat.

*Platina* has not been calcined as yet by fire alone; neither can it be brought into the form of a real calx by the intervention of ſalts. It is brought to a calciform ſtate only from its ſolution in aqua regia, by means of alkaline ſalts.

*Iron* is calcined, by a long continued heat, ſo as to form a browniſh red *ſaffron of iron* (crocus martis aſtringens) which however is otherwiſe much eaſier obtained by ſaline agents, for which divers ways may be taken. By the mere moiſture of the air, for a certain time, iron filings, when expoſed to it by being ſpread out upon an earthen diſh, are by degrees corroded and converted to ruſt. This effect is promoted by ſprinkling the materials continually with water, and ſtill more ſo, by previouſly changing this water with ſome ſaline ſubſtance. *Lemeri* reduced iron by mere water to a black powder, which he therefore called *martial æthiops*, (æthops martialis). For this purpoſe clean iron filings are to be put into an iron pot, and as much water poured upon them as will ſtand a hand's-breadth above them. The iron filings are now to be ſtirred up once, or oftener, every day, in order to prevent their adhering together, and this is to be continued till the iron has loſt its metallic appearance, and is converted to a ſubtle black powder, which is to be dried and paſſed through a fine hair-ſieve. Till the object is attained, the iron muſt be kept continually covered with

water; in the courfe of the operation it lofes but little. The *Crocus martis Zwelferi* is prepared by putting equal parts of iron filings and nitre into a red-hot crucible, keeping it ignited for the fpace of an hour, and edulcorating the refiduary mafs with water. A calx exactly fimilar to this is to be obtained in a fhorter way, by pouring upon iron filings twice their weight of aqua fortis, and after the incalefcence and intumefcence of the mafs is over, edulcorating with water, the crocus martis is thus produced. For the preparation of the *crocus martis fulphuratus*, equal parts of iron filings and fulphur are mixed, and kept in a luted crucible in a very gentle fire, till a fulphureous fmell is no longer to be perceived. The mafs produced by this treatment, may be reduced to powder and elixated with hot water. To this again *Stahl's antimonial faffron of iron*, (crocus martis antimonialis Stahlii) bears a great refemblance. It is obtained by mixing the fcoriæ of martial regulus of antimony, well wafhed with water, (which always, however, ftill contain fome antimonial particles) with two or three times their weight of nitre, and calcining them together for fome time in a red-hot crucible, and then again wafhing and edulcorating them with water. In like manner, iron may be precipitated from pure martial vitriol by means of fixed alkali, to a greenifh powder, which turns to a brownifh-red, when expofed to the air. *Yellow ochre*, the *different red clays*, and the coloured *ferruginous incruftations* yielded by many waters, are proofs that by nature alfo, from effervefcing pyrites and other proceffes evolving of iron, fimilar martial calces are produced, though of a more compound kind. Finally, it is farther remarkable with refpect to iron, that under certain circumftances, in its calcined ftate, it is likewife of a blue colour; it occurs thus native in various ftrata of turf*, and is produced by art, by means of phlogifticated alkali, from iron diffolved in acids; as alfo, by acids from iron diffolved in phlogifticated alkali. Upon this is founded likewife the preparation of *Berlin blue*, which *Diefbach* and *Dippel* difcovered by accident about the beginning of this century. For this purpofe, equal parts of vitriol of iron and alum, or even from two to three parts of alum, are diffolved in boiling water, and the filtered faline lixivium precipitated, while it is warm,

* Vid. *Henry Hagen*'s Chemico-mineralogical Inveftigation of a remarkable blue earth for dying, dug out of the Pruffian turf-bogs. *Konigfberg*, 1772, 4to. With this may be compared the blue earth of Echardfberg. [A] And that found in Scotland by *Sylvefter Douglas*, Efq. and defcribed by him in the Phil. Tranf. Vol. LVIII. p. 181, and feq. [E]

with

with as much of the lixivium of blood (vid. p. 313,) as is requiſite. The precipitate will either be precipitated blue immediately, or not acquire its blue colour till the liquor is filtered from it. The blue colour is, in fact, entirely derived from the iron contained in it, and from its combination with phlogiſton, and is at the ſame time made brighter and more agreeable by the white earth of alum which is precipitated along with it. Hence the colour of the precipitate may be rendered darker or brighter, ad libitum, according to the greater or leſs quantity of alum that is added to it. It depends alſo upon this, that the blue colour of the precipitate is either rendered darker, or elſe, in caſe it has a greeniſh caſt from a portion of unchanged ferruginous earth, more elegant, by a due proportion of vitriolic or marine acid mixed with it, while it is yet moiſt; ſuch addition, however, is always hurtful, becauſe by it, part of the precipitate of iron, as well as of the earth of alum, is diſſolved afreſh, which may be precipitated again by blood-ley. The moſt advantageous way is to precipitate the earth of alum with the ſimple lixivium of pot-aſh, and the ſolutions of vitriol with blood-ley ſeparately, to edulcorate each precipitate likewiſe apart, and, laſtly, to mix them together, while they are yet liquid *. In this operation the pure alkali of the blood-ley is united with the acid of the vitriol, and of the alum, and the phlogiſtic part, which before was combined with the alkali, unites with the martial earth, now on the point of ſeparation, and tinges it blue, with which martial earth the earth of alum mixes at the ſame time; conſequently, the ſaline lixivium remaining contains vitriolated tartar. The precipitate muſt be elixated very often with water. The colouring matter, which tinges the calx of iron blue, may be extracted again from the Berlin blue, by a ſolution of fixed or volatile alkali; ſo that the precipitate will retain only the brown colour proper to it: hence, the alkaline ſalts acquire again the property of precipitating another ſolution of iron with a blue colour. The extract made with the volatile alkali alſo precipitates mercury, platina, and gold of a blue colour.

*Lead* is deprived by fire of its phlogiſtion in different degrees, and on that account alſo are obtained various calces of different external appearance. By the firſt action of the fire it conſumes away to *greyiſh lead aſhes*. On the calcination being continued longer, the calx acquires a yellow colour, and is then called *Maſſicot*. By a briſker and longer continued fire, the ſubſtance, ſo well known by the name

* *Demachy* Laborant im Groſſen. Vol. II. p. 261—273.



of

of *minium* or *read-lead* is obtained, which in England and Germany is prepared in the great*. In England different manufactories of it are eftablifhed; but in Germany only one, which has been carried on time immemorial, at *Rollhofen*, a village near *Nurenberg* †. The operation confifts there of three periods. During the firft eight hours one hundred and eighty pounds of lead are calcined upon a lead hearth, by being continually ftirred with iron hooks, after which, however, it is left in the furnace for fixteen hours, and only ftirred at intervals, in which time the calx of lead gradually acquires a yellow colour. In the fecond period the calx of lead is carried to a mill, ground fmall with water, and wafhed, in order to deprive it of the fmall lumps that remain uncalcined. In the third period, the mafticot, now wafhed and dried, is put into ftone pots, of which feveral are laid horizontally in the *colour* furnace, fo that the flame may go quite round them. Thefe pots are of fuch a fize that thirty-two pounds of mafticot poured into one of them will fill it fomewhat more than a quarter full. A piece of brick is put before the opening of it, in order the better to confine the heat in it. The fire is kept up in this furnace for about forty-eight hours, and the calx in the pots ftirred every half hour, till at length the lower part of the pots has acquired a bright red heat. By the longer continuance of the materials in this red heat, the colour becomes continually finer and finer. The minium being now finifhed, is paffed through a fieve. In the calcination of minium, the following particulars befides are to be obferved; 1. That the colour of genuine minium is a *high yellowifh red*; 2. that the beft coloured red lead muft be perfectly foft and fmooth to the touch; 3. that the old prejudice, that minium cannot be calcined otherwife than by a flame paffing over its furface is evidently erroneous; 4. that in this operation one hundred pounds of lead generally increafe ten pounds in weight; and finally, 5. the origin of the red colour muft be confidered. The two laft articles are ftumbling-blocks for many philofophers, when an explanation of thefe phenomena are required of them. In the opinion of fome Chemifts the colour of minium, as well as the augmentation of its weight, proceeds from the acceffion of pure or dephlogifticated air to the calx, during its ignition. One

* Thefe two preparations were known fo early as in *Geber*'s time. Vid. Traditio Summæ perfectionis et inveftig. magifterii. Lugd. Bat. 1668. 12mo. p. 57, and 101.

† Vid. *D. Charles William Nofe*'s Treatife on the calcination of Minium, particularly in Germany. Nurenberg 1779, 8vo.

would certainly ſuppoſe that, according to the general obſervation, fire will always expel the air from bodies, and conſequently that of the contrary circumſtance, viz. the acceſſion of air during the violent action of fire upon ſuch bodies, would be quite unnatural; not to mention, that freſh calcined minium exhibits no proof of this copious acceſſion of air, but rather appears as a calx deprived of air, and deprives other bodies of their air. As little however as this accords with our ideas, it is equally incomprehenſible alſo, that the ten pounds in the hundred, gained by calcination, ſhould proceed from the pure matter of fire, in which, on other occaſions, hardly any weight is obſerved. This augmentation ſtill continues to be an enigma to me*. With reſpect to the origin of the colour, however, it ſeems probable to me, that during the intenſe and long continued calcination part of the matter of fire unites with it, and the ſurface of the ſmalleſt particles is in ſuch a manner altered by it, that now the light, which is reflected from it upon our eyes, excites in our optic nerves the ſenſation of redneſs.

Among the *Calces of Lead* obtained by means of ſaline ſubſtances, that of *White Lead* indubitably occupies the firſt place. In conſiſts of nothing more than plates of lead corroded by the vapor of vinegar, and calcined, in which ſtate it is known by the name of *Schiefer-weiſs*, or *white-lead in plates*: when it is ground in mills of a particular conſtruction, and waſhed with water, it is called *Ceruſs*†, It has however unfortunately become a cuſtom to add chalk in different proportions to this latter preparation, ſo that moſt ceruſs may be conſidered as adulterated. In Holland there are great manufactories of ceruſs. Lead is calcined in the ſmall way by fuſing it with common ſalt and nitre, as likewiſe

* Were I to propoſe the conjecture thrown out in the former part of this work, relative to the changes that occur in the gravity of the bodies, the increaſe of weight in the converſion of lead by calcination to minium, and other ſimilar caſes might be pretty ſatisfactorily accounted for; as alſo the cauſe, why in the reduction of minium to lead, by the addition of phlogiſton, in which there is an actual acceſſion of an extraneous body, the whole of the additional weight diſappears again. Of all the hypotheſes propoſed, reſpecting the ſubject above-mentioned, this ſeems to me the moſt probable. [A]

The author in this place, refers to the phyſical part of his work (omitted in this tranſlation), in which he had propoſed the matter of fire fixed in bodies, and gravitating towards the ſun, for the ſolution of the phenomena abovementioned: But part of theſe phenomena are better explained by the doctrine of the reciprocal abſorption and emiſſion of air, as firſt promulgated by M. *Lavoiſier*; eſpecially as corrected in the Introduction and various Notes of this Work. [E]

† The preparation of this ſubſtance was known as early as in the time of *Theophraſtus Ereſius*. l. c. § 100.

likewife by precipitating the lead from a folution of lead in nitrous acid, or from a folution of fugar of lead in common falt, or in the marine acid to *plumbum corneum*, or elfe with vitriolic acid to *vitriol of lead*.

*Tin* is not fo eafily calcined by fire as lead; when it is, it yields a yellowifh calx; hence it is ufual to attempt to promote this operation by the addition of a quantity of lead. Saline bodies however have more effect in this way. When tin has nitrous acid poured upon it fo as to cover it, it is corroded by this menftruum to a beautiful white calx, which after being perfectly edulcorated, may be very advantageoufly ufed as a colour for painters. The fame thing is faid to be effected with vinegar, and the pigment called *Spanifh white* is obtained by it. Farther, a white calx is alfo obtained from all its folutions in acids in general, by employing either the vitriolic or marine acid, or the nitrous and marine acids together, and precipitating it together with alkaline falts; alfo from butter of tin, by water alone. One part of tin fufed with two of nitre yields, after being well wafhed, a white calx; in this operation flowers of tin alfo are fublimed at the fame time, which might eafily be collected for ufe in a tubulated retort.

*Copper* calcined by fire alone, leaves behind it a calx of a brownifh-red colour, but it is corroded and converted into a green or black calx by all falts; of which thofe moft in ufe are the following. *Verdigrife* is prepared at Montpelier, in large manufactories; plates of copper are there laid in ftrata with the hufks of grapes, in confiderable quantities, and the whole fuffered to remain in that fituation for a long time. In this operation the hufks become heated, their acidulous vapor gradually corrodes the whole of the copper-plates, unites with them in abundance, and changes them into verdigrife. On account of the vegetable acid contained in it, its colour does not ftand, when expofed to the air*. In this refpect the *Brunfwick Green*, difcovered by the two brothers *Gravenhorft's*, at Brunfwick, and prepared by them in large quantities, is much preferable to it; as its colour is durable. Nothing certain can be faid of the preparation of this pigment, which has hitherto been kept a fecret. Befides this, many other copper colours are ufed with advantage, particularly when an ounce of Cyprian vitriol is diffolved together with one or two ounces of alum or Epfom falt, in three or four of boiling water, filtered, precipitated with a folution of fixed alkali, and edulcorated with water. By way of making a change in the colour, one

† This colour alfo has been long ago defcribed by *Theophraftus Erefius*. Ibid. § 101.

drachm

drachm of martial vitriol may, if thought proper, be diſſolved at the ſame time with the ſalts firſt mentioned: inſtead of Cyprian vitriol too, a ſolution of half an ounce of copper in the marine acid will anſwer the ſame purpoſe. To this head alſo may be referred the green colour, which is obtained by degrees from a ſolution of common ſalt and Cyprian (or blue) vitriol, by putting copper plates into it*. Another beautiful colour is alſo obtained when two parts of clippings of copper mixed with one of ſal ammoniac and moiſtened with water, are kept with a gentle heat till the copper is entirely corroded, after which the ſalts are elixated with water, and the colour waſhed. *Scheele's green colour* alſo deſerves to be mentioned here; to produce which, one pound of blue vitriol is diſſolved in a ſufficient quantity of boiling water, to which is immediately added a ſolution of one pound of purified alkali, and five ounces and a half of pulverized white arſenic in eight pounds of boiling water, and the precipitate ariſing from this mixture is well elixated, ſeparated and dried. A green colour is made by mixing a portion of ſlaked lime with a proportional quantity of ſolution of copper, in which operation the maſs muſt be ſtirred till the copper is united with the calcareous earth, and the ſuperincumbent water has no longer any colour. The union is accelerated by heat. The ſolution of copper which is obtained adventitiouſly in the ſeparation of ſilver from aqua-fortis by means of copper, is moſt advantageouſly uſed for this purpoſe.

In moſt of the above-mentioned calcinations of metals by fire, or by the intervention of ſaline ſubſtances, the phlogiſton of the metals is more or leſs diſſipated and loſt.

*Silver* as yet could never be calcined by fire alone; even the different ſaline ſubſtances can do no more than reduce it to a calciform ſtate; in all ſuch combinations it retains its original compoſition unaltered. When it is diſſolved in nitrous acid, and precipitated with pure marine acid, or with neutral ſalts which contain this acid, the ſubſtance called *Luna Cornea* is produced, i. e. ſilver combined with marine acid, which alſo may be obtained in the dry way, by the diſtillation of corroſive ſublimate with ſilver. When ſilver is precipitated from its ſolution by an alkali, a mere precipitate of ſilver is produced; but if vitriolic acid be

* Chemical Experiments by a Society in the Erzgeburge. Berlin, 1753—59. Experiment 3. 5. 8. 10. 14. 16. & 18—50—137. 141—273. 278—282. 287—426. 429. 434. 437. 637. —627. 631. 634 & 636.

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ufed for this purpofe, the precipitate exhibits a vitriol of filver, as it confifts of filver and vitriolic acid, which combination may alfo be effected in a direct manner by diftilling oil of vitriol over filver.

This property it has in common with *Gold*, which has never been calcined even by the fierceft fire of a glafs-houfe furnace. In a calciform ftate merely, gold may be precipitated in different ways from its folution in aqua-regia, in which operations at the fame time certain portions likewife of the menftruum, or of the precipitant will remain in union with it. The properties of *Aurum fulminans* and the method of preparing it, prove this very plainly. In the *mineral purple*, the gold appears to be more of a calx-like nature, though it is not fo in fact: by this appellation is diftinguifhed a dark-red precipitate of gold, which imparts a purple colour to fufed glafs; for the preparation of it, the gold is precipitated from its folution by a folution of tin. In order perfectly to attain this end, particular care muft be taken to ufe pure gold and pure tin. A quantity ad libitum of gold is diffolved in aqua-regia, in which operation no particular occurs worth mentioning. The folution of tin, on the other hand, muft be prepared with much greater care. Two parts of nitrous acid and one of marine acid, in cafe they are both of the fame ftrength, will commonly form an aqua-regia, in which tin is diffolved in the cold without any great violence, fo that only a very inconfiderable portion of black powder will remain behind. If the tin is found rather to be corroded to a white calx than diffolved, a little more marine acid is added. The whole folution muft be made without heat, and the tin put in by little and little, and when this is diffolved, a fmall portion is added again, till at length a perfect faturation takes place, which is obferved to be the cafe when the folution acquires fomewhat of a brownifh whey-colour, and the tin is no longer perceived to be acted upon. It is alfo proper that the folution of tin fhould be made frefh each time. The folution of gold is now to be diluted with one hundred times its quantity of diftilled or rain-water, and to this, (the liquor all the while being ftirred continually with a clean little ftick) is added the folution of tin, drop by drop, till the liquor ceafes to become turbid with it. After the precipitate has entirely fubfided to the bottom, the fuperincumbent water is decanted, the precipitate is farther properly edulcorated, and gently dried. In this operation, the gold feems to be precipitated by the tin, merely in virtue of their intimate affinity to each other; as, in fact, they both unite together during the precipitation, and the precipitate confifts of gold and tin.

In

In all the calciform preparations of metals mentioned above, whether obtained by fire, or by means of faline intermedia, their ready *folubility*, *their corrofivenefs*, *there colour*, and efpecially *their increafe of weight*, are in *fome* of thofe obtained by the former method, and in *all* thofe indifcriminately that have been prepared in the latter way, very remarkable. The changes which the metals undergo by the bare action of the fire, depend partly upon the fubftraction of a portion of their phlogifton, when they are of fuch a nature, as to be capable of parting with it; but, on the other hand, it may alfo be difcovered from other properties, that thefe changes may proceed from the matter of fire combined with them, where no lofs of phlogifton can be alledged. Upon this feems to depend the folubility, corrofivenefs, colour and increafe of weight of mercurius precipitatus per fe, or calcined mercury, which therefore perfectly recovers its metallic appearance from volatile alkali only; and, on the other hand, imparts caufticity to this falt. I have elfewhere fhewn the improbability of the affertion of fome chemifts, that thefe changes are derived from the acceffion of air during the calcination. That various calces emit air during their reduction cannot be admitted as a proof, as this may for the moft part proceed from the reducing fubftances, which without any fuch affiftance yield air of themfelves; and indeed thefe calces are commonly diffolved without great effervefcence, and befides attract air from other bodies, and confequently have not this property, which yet they ought to have on the improbable fuppofition of any acceffion of air having taken place. Might not the air, attracted by calcined mercury and lead, be derived from a fmall portion of thefe metals actually deftroyed by the fire? The following circumftance, at leaft, ought to be confidered, that the fame weight is never obtained in any metal, as it had before the calcination*. On the other hand, moft of the properties of the metallic calciform preparations made with the affiftance of faline materials, depend partly upon fome faline fub-

* The increafe of weight in metals that are calcined, evidently proceeds from the abforption of air that takes place in them, either from their parting with their phlogifton in a certain degree of heat in exchange for this fubftance, as in *combuftion*; or in confequence of their decompofing *water*, and thus generating inflammable gas; or *acids*, and thus generating nitrous gas, fulphur, fulphureous gas, &c. The corrofive property and caufticity of metallic calces proceed, as M. *Berthollet* has fhewn in the Mem. de l'Acad. des Sc. 1780, from their attraction to phlogifton. The other properties above-mentioned have not as yet been fatisfactorily accounted for either upon M. *Wiegleb*'s or any other fyftem. [E]



ftance

ſtance actually combined with them, and partly upon the acceſſion of air, water, and the matter of fire. At leaſt all metallic precipitates indubitably ſtill contain a portion of the acid of their menſtruum which cannot be ſeparated from them boiling water, as I ſhall endeavour to prove in a future publication *.

Finally,

* The experiments of *Lavoiſier*, *Bayen*, and *Berthollet*, all unite to contradict our author's reaſonings in this paragraph. Metallic calces have undoubtedly for the moſt part their *increaſe of ſolubility*, their *acrimony*, their *colour*, and particularly as theſe chemiſts have demonſtrated their *increaſe of weight*, from the pure air combined with them, during their calcination, to which, however, except in the laſt article, we muſt be allowed to add, the loſs of part of their phlogiſton. So that theſe *calciform precipitates* of our author are for the moſt part *real calces*, formed, not by fire indeed, but by acids and water. Accordingly, the calces and calciform precpitates of mercury may, in imitation of the authors of the *Nomenclature Chimique*, (but avoiding their periphraſtic expreſſions, and the equivocal term of *Oxid)* be diſcriminated from each other in the following manner.

| | | |
|---|---|---|
| *Hydragyrites*, or Hydrargyrite (*the proper calx of Mercury*, | commonly called | *Precipitate per ſe*, |
| *Hydrargyrites Vitrioloxicus*, or Vitrioloxic Hydrargyrite, | | *Turbith mineral* |
| *Hydragyrites Nitroxicus*, or Nitroxic Hydrargyrite, | | *Red precipitate* |
| *Hydrargyrites triturâ*, or Hydrargyrite by triture, | | *Æthiops per ſe* |
| *Hydrargyrites Epimurioxicus*, or Epimurioxic Hydrargyrite, | | *Æthiops of* Berthollet. |

The firſt and third of theſe calces are ſuppoſed to be exactly the ſame, and conſtitute the moſt perfect calx of mercury known at preſent. The two laſt are likewiſe in every reſpect the ſame, except in their formation: neither do they ſeem otherwiſe to differ from the black calx precipitated from the nitrous acid by volatile alkali: and all three conſtitute the moſt imperfect calx of mercury, which containing the leaſt air and the moſt phlogiſton of any, approaches neareſt to the metallic ſtate. Indeed there is great reaſon to ſuſpect that by proper management the calx of mercury (and perhaps of every other metal) may be ſeparated from all the acids preciſely in the ſame ſtate.

From the experiments of M. *Berthollet* and others, it appears that hydrargyrite or the calx of mercury, with a certain quantity of marine acid, forms corroſive ſublimate; but that there is no more air in the latter than in the former preparation, and that corroſive ſublimate contains no more air than other metallic ſalts, as all metals muſt be calcined previous to their ſolution in acids; but mercury, not parting eaſily with its phlogiſton, does not decompoſe water as ſome other metals do, and therefore muſt have the pure air requiſite for its ſolution preſented to it in a way in which it may eaſily attract it, as, when in the form of calcined mercury it already contains air, or in the various other proceſſes in uſe for preparing corroſive ſublimate.

It likewiſe appears that the *black* calx of mercury, or Æthiops per ſe, is compoſed of this metal and pure air, but leſs air, and conſequently more phlogiſton than the *red* or perfect calx; that by the addition of common marine acid, it is converted into calomel; and from thence, by a farther addition of acid and air ſucceſſively paſſes to the reſpective ſtates of ſweet mercury, and white precipitate, in which the metal is ſtill more dephlogiſticated, and has acquired a ſtill greater ſhare of cauſticity and ſolubility; and laſtly, by the acquiſition of more air and more acid, is converted into that moſt ſoluble and highly cauſtic ſubſtance, known by the name of corroſive ſublimate.

But

Finally, there ſtill remain to be mentioned ſome *metallic preparations made by means of ſulphur.* If we conſider that moſt of the metals in their ſtate of ores have been combined with ſulphur, which muſt be ſeparated from them in the firſt inſtance, we may eaſily conceive that, when they are united again with ſulphur, they muſt return to a ſimilar ſtate; and this will be found to be the caſe with moſt of the metallic preparations mentioned here, that can be made with the aſſiſtance of ſulphur. *Manganeſe* unites to ſulphur with great

But to return to the ſubject of calces in general and their nomenclature; the reader will eaſily perceive that in the denomination of theſe ſubſtances we have purpoſely avoided uſing the epithets red, black, &c. as tending only to promote confuſion: that the termination with which we have deſigned calces in general is in the ſame as that by which we have before diſtinguiſhed the ſimple earths, to which theſe ſubſtances approach in their appearance, as well as their nature; and laſtly, that we have diſtinguiſhed each calx by an ephithet, demonſtrative of the ſubſtances by which the metal has been calcined, and as theſe are generally acids, we have expreſſed that circumſtance alſo by the termination: thus, *Turbith mineral* is termed (not Vitriolic) but *Vitrioloxic Hydrargirite*, by which is expreſſed a calx of mercury formed by means of the vitriolic acid; but not retaining any of that acid in its compoſition. When either the menſtruum, precipitant, or calcining ſubſtance is retained, it may be proper to point out that circumſtance, by terminating the epithet in the manner of a participle, as, e. g. Fuluminating gold, *Chryſites Ammoniatus*, or ammoniated chryſite, And as the Greek names of moſt of the metals are tolerably familiarized to our ears by the modern languages, we ſhould in general prefer uſing them in compoſition: thus, the terms *Chryrite, Argyſite, Chalcite, Chalybite, Molybdite,* &c. all derived from the Greek, accord better with the Greek termination *ites*, and therefore ſound better than *Aurite, Argentite, Cuprite, Ferrite, Plumbite*, taken from the Latin names of the ſame metals. For this reaſon alſo, we would recommend the terms Oxychryſon, Oxargyrum, Oxychalcum, &c. inſtead of the appellations of Oxyaurum, Oxyargentum, Oxycuprum, which out of complaiſance to prejudices, not ſo prevalent in this iſland as amongſt ourneighboursthe French, we have adopted in the table, exhibiting the claſſes and genera of ſalts.

We ſhall conclude this note with exhibiting, nearly in the order obſerved by our author, the names of the principal metallic calces and calciform preparations, according to the *Nomenclature Chimique*, with ſcarcely any other alteration than merely that of the term Oxid, in the manner propoſed above.——MANGANESE. The white calx, *white magneſite.* The black, *black magneſite.* COBALT. Saffre, *grey cobalite with ſilicite.* Smalt, *vitreous cobalite.*—ARSENIC. White arſenic, *white arſenicite.* Flowers of arſenic, *white arſenicite ſublimed.*—ANTIMONY. Argentine flowers of antimony, *white antimony ſublimed.* Diaphoretic antimony, Materia perlata, ceruſs of antimonite, *white antimonite by nitre.* Powder of Algaroth, *murioxic antimonite.* Bezoar mineral, *Murio-nitroxic antimonite*—ZINC. Flowers of zinc, *ſublimed zincite.* Diaphoretic zinc, *zincite by nitre.* —BISMUTH. Flowers of biſmuth, *ſublimed biſmuthite.* Magiſtery of biſmuth, or Spaniſh white, *white nitroxic biſmuthite.*—IRON. Crocus martis aſtringens, *brown chalybite.* Ochre, *yellow chalybite.* Colcothar, *red chalybite.* Martial Æthiops, *black chalybite.*—LEAD. Maſticot, *yellow molybdite.* Minium, *red molybdite*, (or rather *ſaturnite*, in order to avoid confounding it wih *molybdæna.*) Litharge, *ſemivitreous ſaturnite.* White lead, *white acetoxic ſaturnite.*—TIN. Flowers of tin, *ſublimed ſtannite*, or *caſſiterite.* Putty, *grey ſtannite.*—COPPER. Verdigriſe, *green chalcite.*—SILVER. Fulminating ſilver, *ammoniated argyrite.*—GOLD. Fulminating gold, *ammoniated chryſite.* Purple of caſſius, *ſtannated chryſite.* [E]

difficulty. *Bergman* affirms however, that eight parts of the calx of manganefe, fufed in a glafs retort with three of fulphur, formed a yellowifh green mafs, the metallic part of which was diffolved by acids, and the fulphur left behind. *Arfenic* acquires a yellow or a red colour, accordingly as more or lefs fulphur is combined with it. *Yellow arfenic* or *orpiment* is produced by mixing and fubliming together, from fix to ten parts of white arfenic with one of fulphur. For *red arfenic* or *realgar*, one part of fulphur, and from three to five of arfenic are to be mixed together and treated in the fame manner. The former is an imitation of native orpiment, and the other of native fandarach or realgar. Sulphur and arfenic unite eafier, when the latter is ufed in its reguline ftate, or in that of grey flowers of arfenic. The combination is effected equally well by merely fufing them together in a clofe veffel. It is commonly fublimed in the great from arfenical and fulphureous pyrites mixed together. *Pure regulus of antimony* fufed with a third of fulphur, is mineralized again, and rendered fimilar to crude antimony. Three parts of crude antimony triturated for the fpace of feveral days with one of mercury, to a fine powder, till the whole of the mercury difappears, forms *antimonial æthiops*. When crude antimony, reduced to a fine powder, is boiled for a fhort time with a ftrong folution of alkaline falt, or with a cauftic ley, filtered while it is hot, and fuffered to grow cold, a reddifh brown powder is precipitated, which bears the name of *Kermes mineral*, or *poudre des Chartreux*.

The refiduary ley is to be fomewhat diluted with water, and poured again upon the antimonial powder, that remained undiffolved before, then boiled up again, and in every refpect treated as at firft, till at length all the antimony is diffolved, or the whole of the ley is gradually confumed. With this fpontaneous precipitate, the production of which depends upon the ftrong concentration and faturation of the ley, the *golden fulphur of antimony* bears a great refemblance. This, according to the antient formula of *Bafil Valentine*, is precipitated by an acid from a folution of antimony made with alkali; and when the precipitation is performed at three or four feparate intervals, three or four precipitates are obtained different in colour and effect; of thefe, the laft, which is of a lighter colour, is efteemed to be the beft. Since it is now fettled, upon what its fuperiority depends, it may be obtained with more eafe and certainty than before. My method is to boil two parts of pulverized crude antimony, and one of pulverized fulphur, with as much ftrong cauftic ley as is fufficient to diffolve the whole. After this the ley is filtered, and the precipitation made with diluted vitriolic acid, the precipitate repeatedly wafhed with frefh water, and laftly dried.

In

In the Kermes there are more antimonial particles, whence it causes an easier vomiting. In the golden sulphur of antimony the proportion of sulphur is greater, by which the action of the antimonial means particles is rendered milder.

If *mercury* and sulphur be mixed together in equal weights, and in a a serpentine-stone mortar, till there is not the least vestige of quicksilver to be found, the coal-black powder produced by it obtains the name of *Æthiop's Mineral.* The union of these two substances may be expedited by fusing the sulphur over a gentle fire; but the mass is not easily pulverized afterwards *. From these two ingredients, taken in a different proportion, *cinnabar* is acquired; the artificial method of compounding which was known so early as in *Geber*'s time. The proportion is very differently prescribed in books of chemistry; but none of them is more accurate than that which is founded upon the decomposition of the cinnabar. *Wenzel* indeed asserts that he had found in this way, that one ounce of cinnabar contains three hundred and seventy-seven grains and a half of mercury, and one hundred and two grains and a half of sulphur; according to this, about three pounds three quarters of mercury should be taken to one of sulphur. With this pretty nearly accords the account given by *Ferber*, of the proportion in which cinnabar is prepared in great quantities at Amsterdam, and which consists of one hundred and seventy pounds of mercury, and fifty of sulphur. This, nevertheless, does not seem to be the true proportion. Fine bright red Dutch cinnabar yields nearly seven parts of mercury, and I have actually prepared such with one part of sulphur and seven of mercury. *Ferber* therefore has either been wrongly informed, or, in the Dutch way of preparing it, in which the mixture is set on fire, a great deal of sulphur must be dissipated. The sulphur is fused by a gentle heat, the mercury added to it, and both well mixed together. This mass is afterwards set upon a genle fire, in a convenient vessel, till it is thoroughly heated, when it is sublimed with a very intense heat. The brisker the fire is, and the quicker the sublimation can be performed, consistently with the nature of the vessels, the finer will be the colour of the cinnabar. The alteration which the black combination of mercury and sulphur undergoes in this operation, by being changed to a beautiful crimson, is best illustrated by the *preparation of cinnabar without fire*, which was first described by *Godfrey Schultz*, as long ago as in the year 1687 †. This is made by mixing some mer-

* For the method of obtaining *Æthiop's Mineral* via humida, vid. *Neueste Entd. in der Chemie*, Vol. IV. p. 153. [A]

† *Crell*'s Chemical Archives, Vol. I. Sect. II. p. 143. [A]

cury

cury in its metallic ſtate, or a ſolution of it, or corroſive ſublimate mercurius dulcis, white precipitate, or turpith mineral, with Beguin's ſpirit of ſulphur, and ſhaking or triturating them together for a time, by which means the mercury, or the preparations of it above-mentioned, gradually acquire at firſt a black, but at laſt a fine bright cinnabar-red. The ſame change of colours occurs in this operation as in that which is effected by fire; therefore the ſame cauſe muſt operate in both inſtances. Agreeably to Sir *Iſaac Newton*'s doctrine it is generally ſuppoſed, that the colours of bodies depend upon the difference of their ſurfaces only, accordingly as theſe reflect the rays of light in this or in that manner. But it is probable that the mere reflected light is not alone the cauſe of the colour, but that each body contributes in ſo far to the colour by the different nature of its ſurface, as the reflection of the light is determined by it. For each colour, therefore, a particular determinate conſtitution of the ſurface of the body is requiſite, and each particular ſtate or conſtitution of the ſurface muſt neceſſarily proceed from ſome particular cauſe in the compoſition of the body. As therefore mercury itſelf is only of a bright ſilver hue; but, on the other hand, when combined with different ſubſtances, exhibits ſometimes this and ſometimes the other colour, the ſurface of its ſmalleſt particles muſt neceſſarily be altered in ſuch a manner by theſe different ſubſtances combined with it, as to cauſe at one time one colour and at another time another. For the mercury therefore to be ſo conſtituted, that our optic nerves may acquire the ſenſation of the red colour, a particular cauſe will be requiſite, by which its ſurface ſhall be diſpoſed preciſely in in ſuch a manner, that from the light reflected from it, we ſhall have the ſenſation of redneſs. Now, as in the calcination of mercury by mere fire alone, this metal is found to acquire a red colour, I think it probable that the matter of fire, by its combination with the ſmalleſt particles of the mercury, is adapted to diſpoſe the ſurface of this latter preciſely ſo, as it ought to be in order to excite in us the ſenſation of redneſs. From ſimilar effects I infer ſimilar cauſes. What, therefore, in this and in like manner, in the other calx of mercury prepared with nitrous acid, cauſes the red colour, muſt alſo be the occaſion of the redneſs of cinnabar. This cauſe it is not difficult to diſcover. In the former preparation of cinnabar the fire does every thing: in the other preparation, the matter of fire exiſts in the Beguin's ſpirit, which received it from the quick-lime uſed in preparing this ſpirit. Inſtead of Beguin's ſpirit a concentrated cauſtic ley, impregnated with ſulphur, produces the ſame effect upon mercury. It ſeems alſo, that

that the fine colour of the golden ſulphur of antimony, in the preparation of which a cauſtic ley has been uſed, depends partly upon the combination of the matter of fire with it. Formerly, when a very high opinion was entertained of a peculiar ſulphur belonging to antimony, the cinnabar of antimony was ſuppoſed to poſſeſs an extraordinary degree of efficacy, but ſince the perſuaſion has gained ground, that it is quite ſimilar to common ſulphur, it has been diſcovered, that the cinnabar compound of it is not a whit better than any other. This ſubſtance is obtained indirectly and adventitiouſly in the preparation of the butter of an antimony from two parts of corroſive ſublimate and one of antimony, by ſubliming the reſiduum ſeparately.

*Iron* is mineralized by ſulphur and made to reſemble martial pyrites. For this purpoſe nothing more is neceſſary than to rub an iron, glowing with a white heat, over with ſulphur, when it will be immediately melted, and fall off in drops. From equal parts of *Lead*, beaten into plates, put into a crucible, ſtratified with ſulphur, and urged with a red heat, ariſes an artificial galena, which is uſed under the name of *plumbum uſtum*, or *burned lead*. An artificial *tin ore* is obtained by fuſing an ounce of tin, and urging it with an obſcurely-red heat, and then adding two or three drachms of ſulphur to it and ſtirring it well. The mixture will take fire, and be converted into a black powder, which afterwards is made to fuſe in a crucible and poured out. Hither too may be referred the preparation of *aurum muſivum*, which properly conſiſts of tin and ſulphur, and forms an artificial *tin mica*. I know of no older preſcription than that which occurs in *Alexius Pedemontanus* under the name of *Purpurina*; the proportion of the ingredients, however, is now better known. The following proportion, preſcribed by *Woulfe*, I have found to be the beſt: it conſiſts of twelve ounces of tin, ſeven of ſulphur three of ſal ammoniac, and three of mercury. The tin being fuſed, the mercury is added to it; the maſs is then triturated and afterwards mixed with the ſulphur and ſal ammoniac. The powder is now put into a matras placed rather deep in ſand, and treated for ſeveral hours with a gentle heat, which at length is increaſed, and thus continued for ſeveral hours longer. The tin is developed by the marine acid of the ſal ammoniac; and upon this combines with a portion of the ſulphur; the reſt of the ſal ammoniac, ſulphur, and mercury are ſublimed. At the bottom of the matras, however, the tin is found of a gold-coloured micaceous appearance, throughout its whole ſubſtance, provided the proper degree of heat has been applied. The heat muſt be but moderately ſtrong, that the redundant materials may be ſublimed; but when the fire is too ſtrong, the aurum muſivum fuſes to a black maſs, compoſed

of

of ſpiculæ in appearance much reſembling antimony. Hence a ſimilar ſolid black cake is frequently found among the moſaic gold, from which it may be inferred, that the fire has been either too fierce or too long continued. But when the proper degree of heat has been applied, the whole of the tin is changed into this beautiful reſplendent gold-coloured maſs. By treating *Copper* in a manner ſimilar to that mentioned for lead, *burnt copper* (aes uſtum) is obtained. In order to obtain a *yellow copper ore*, equal parts of iron and copper-plates, beaten out thin are put into a crucible, (the iron undermoſt) and another crucible, the bottom of which is ſtruck out, is luted to it. When the metals are red-hot, ſulphur is projected upon them by degrees, and the maſs fuſed by the blaſt of pair of bellows. An artificial *vitreous glaſs ore* is acquired by ſtratifying ſilver and ſulphur together in a crucible, and fuſing them by a fire gradually increaſed. With lapis pyrmeſon, calx of iron and ſilver, the *red ſilver ore* is imitated *.

As I am now come to the concluſion of the doctrine of metals and their various preparations, I cannot help making ſome mention of an extravagant fancy of our anceſtors, which ſtill ſubſiſts even in our days.

The various changes which metals undergo, ſome points of reſemblance in which ſeveral of theſe ſubſtances coincide, the alteration of their colour produced by certain additaments, by which ſome of them may be made to reſemble gold and ſilver, and laſtly, the great eſtimation to which theſe two latter metals are arrived, may poſſibly have induced mankind, at a certain period, to imagine that gold and ſilver might be compoſed by art as well as by nature. They probably concluded in the ſimplicity of their hearts, that as ſo many bodies in nature are imitated by art, gold and ſilver might be imitated in like manner. It can be proved by the veſtiges found of it in ancient writings, that the obſervation of the effects of certain metals upon copper gave riſe to this idea. I ſhall therefore explain ſome of their notions, and both in what manner they believed that they might attain their end, and what they imagined concerning the compoſition of metals, from which the abſurdity of this chimerical fancy will evidently appear.

* The ſulphureo-metallic preparations are, according to the *Nomenclature Chimique*, nearly as follows:

ARSENIC. Orpiment, *yellow ſulphurated arſenicite.* Realgar, *Red ſulphurated arſenicite.*—ANTIMONY. Common mineralized antimony, *ſulphurated antimony*, liver of antimony, *ſulphurated antimonite.* Crocus metallorum, *ſemivitreous ſulphurated antimonite.* Kermes mineral, *red ſulphurated antimonite.* Golden ſulphur of antimony, *Orange-coloured ſulphurated antimonite.* Glaſs of antimony, *ſulphureo-vitreous antimonite.*—MERCURY. Æthiops mineral, *black ſulphurated hydrargyrite.* Cinnabar, *red ſulphurated hydrargyrite.*—TIN. Moſaic gold, *ſulphurated tin.*—IRON. Pyrites, *ſulphurated iron.*—COPPER. Copper matt. *ſulphurated copper.*—LEAD. Lead matt, *ſulphurated lead.* [E]

This

This imaginary poſſibility being pre-ſuppoſed, it was very natural for them firſt to be ſtruck with the idea of obtaining their object by means of the very materials and principles of which gold and ſilver are prepared by nature. They therefore endeavoured to acquire a knowledge of the ſubſtances with which the metals are moſt intimately connected in the mines, ſuppoſing that the metals muſt neceſſarily have been formed from theſe. From this conſideration aroſe their ideas of the conſtituent parts of metals. Now upon this ſubject, the oldeſt of the chemiſts, *Geber* ſays very plainly, that his predeceſſors (who were the firſt alchemiſts) acknowledged a fetid ſpirit, and a quick or dry water, by which *ſulphur* and *mercury* muſt be underſtood to be the *conſtituent parts of metals.*—Which were therefore two only in number*.

But *Geber's* cotemporaries had even then formed a different opinion; becauſe the ores of ſilver and other metals were often found deſtitute both of mercury and ſulphur; while both of theſe latter were found in their proper ores; therefore thoſe natural conſtituent parts of the metals muſt be underſtood; but that theſe were in a tranſmuted *earthy form*, fit only to be diſſolved in vapor, which vapor immediately afterwards, and without the intervention of any other ſubſtance, generated the metals †. From the opinion of theſe, *Geber* himſelf differs in this, that he allows of *three conſtituent parts of metals*, viz. *ſulphur*, *arſenic* and *mercury* ‡. From theſe, in his opinion, all the metals originated. But reſpecting the change of the baſe metals into gold and ſilver, he believed that it depended upon the proper application of marcaſite, magneſia, tutty, antimony, lapis lazuli, and the purification of the metals with different ſalts §. But having obſerved, that by this means, eſpecially in copper, the colour of ſilver and gold was produced, which yet was deſtroyed again in the fire, his view as well as that of all the chemiſts of his time was, to purify theſe *volatile ſpirits*, as he called them, by ſublimation; and to make them fixed in the metals.

Moreover, after *Geber* and many others of his followers had been diſappointed in their views, and after the high degree of perfection and the fixity of

* Chemia, ſive traditio ſummæ perfect. Ludg. Bat. 1668. 12mo. L. I. c. XXV. [A]

† L. c. XXVI. [A] ‡ I. c. C. XXVII.

§ I. c. C. XXXIX. Here it muſt be obſerved, that according to *Geber's* deſcription, that ſubſtance which he called arſenic, is our orpiment, and that by the names of marcaſite and magneſia, certain kinds of martial pyrites muſt be underſtood; as appears in ſeveral paſſages of his work, by his deſcription of theſe bodies, and as may alſo be proved from other writings. [A]

the two noble metals were better afcertained; while, on the other hand, thefe properties were not difcovered in any of the other metals, fince moft part of them were condenfed in the fire, and fome of them were found to be quite volatile; others adopted the extravagant notion, that the fole aim and fcope of nature in all the metals, was the formation of gold and filver. Thefe, therefore, confidered all the bafe metals as imperfect gold and filver, and believed that nature had not been able to attain her end, becaufe fhe had been prevented by the premature extraction of the ores from the mine. This opinion became ftill more probable by the obfervation, that fome gold or filver was to be found in almoft every metal. Now, agreeably to this, it was natural for this chemical fect to imagine it poffible to perfect thefe bafe metals and to convert them into gold and filver by a long-continued gentle heat, and by maturating fubftances of various kinds. In thofe times, therefore, the grand object of the chemifts was the fixation of mercury and other volatile metals, and their motto was; *Ubi natura definit, ibi incipiendum.*

Laftly, there was yet another fect, which believed that the growth of metals proceeded in the fame manner as that of the bodies of the two organized kingdoms, and that confequently every metal arofe from its peculiar feed. But as they could not find the feeds of gold and filver in nature, they endeavoured to develope thefe metals themfelves in fuch a manner that, according to their opinion, they might become fo prolific and efficacious, as to change the bafer metals into their own fpecific nature. But the whole will ever remain a mere chimera.

As to *Geber's* three conftituent parts of metals, *Bafil Valentine* afterwards rejected arfenic and fubftituted *falt* in its place. This opinion *Ifaac Holland* alfo adopted after him; and fince that time, fulphur, falt and mercury, were long held up as being the three conftituent parts of metals, which many likewife, in their own opinion, have feparated from the metals. With this both of them alfo combined the ftrange idea, that thefe imaginary conftituent parts were of a peculiar nature in each metal; whence again various collateral ideas have arifen with regard to the tranfmutation of the bafer metals, in conformity to which, they endeavoured to tranfmute the bafe metals by means of fome one or other of thefe pretended conftituent parts of the noble metals.

*Theophraftus Paracelfus*, it is true, likewife adopted the doctrine of the three conftituent parts of metals; but declared at the fame time, that by thefe appel-

lations such substances only must be understood as bore a certain resemblance to sulphur, salt and mercury, and that not only metals, but all other bodies consisted of them. Every thing that was inflammable he called sulphur, the volatile parts mercury, and the fixed acrid parts, salt.

The doctrine of the constituent parts of metals was once more reformed, and that by *Becher*, who proceeded with the three, just in the same manner as *Geber's* cotemporaries had done with the two, viz. he pronounced the three constituent principles of metals to be three peculiar earths, the first of which he called vitrescent, the second inflammable, and the third mercurial earth. This theory was still more enlarged by *Stahl*, but at the same time in some measure likewise restricted, since he pretty evidently rejected the mercurial earth, pronouncing it to be the same with the inflammable. It may therefore with more reason be asserted, that *Stahl* reduced the elements of metals to two again; and especially that he placed the idea of their combustible parts in a clearer light, which idea, the hints dispersed in different parts of *Geber's* writings, doubtless enabled him to develope.

Now from the confusion as well as the mutual and perpetual opposition of these ideas, no inference more certain can be drawn, than that to this present time, we know just nothing at all of the composition of metals. In fact, what is it to know, that of all the base metals and semi-metals, each consists of an absolutely specific elementary earth, and the universal principle, phlogiston; and that mercury, platina and gold, are as yet indestructible? what is this compared to all that which we do not know concerning them? If we will not deceive ourselves, we must confess that it amounts to a mere nothing. As long however as the composition of metals continues to be involved in such obscurity as it hitherto has been, the idea of the transmutation of them must be looked upon as a mere phantasm.

Should we even be inclined in this respect to admit *a position so destitute of proof*, as that the difference between the metals depends upon the different proportion of their constituent parts (which however cannot possibly be of the same nature in every one of them) and upon a stronger or weaker combination arising from thence; we can notwithstanding this, affirm, that to this very day, the artificial generation of metals, or the transmutation of the base metals by different additions, or by altering the proportion of their constituent parts, is utterly impracticable, because the object aimed at depends upon a condition which nobody has

hitherto fulfilled. This condition is an accurate knowledge of the conftituent parts of metals and their proportions, together with the feparation of thefe parts from each other, and combination of them afrefh, circumftances of which however we are entirely ignorant. We know ten times more of the compofition of various organized bodies than we know of metals, and notwithftanding this, no artift has as yet been able to imitate them after nature, and therefore we muft be much lefs able to attain this view with refpect to metallic bodies, and among thefe ftill lefs with refpect to filver and gold. All the knowledge of a chemift, in relation to metallic bodies, confifts merely in knowing the moft advantageous method of obtaining them from the womb of nature, and of purifying them; what effects they produce upon other bodies, what they produce in combination with other bodies, and how all thefe particulars may be applied to any ufeful purpofe*.

* It may not be amifs to fubjoin in this place a Table of the *Specific gravities* of the different metals, together with the degrees of heat at which they melt, and the degrees of their tenacity eftimated by the weight which a wire of each metal, one tenth of an inch in diameter, is able to fupport.

It may be neceffary to obferve, that the melting heat as exhibited by Mr. *Wedgwood's* new thermometer is univerfally fuppofed to be neareft to the truth.

| METALS. | Specific Gravity. | Melting Heat. | | Degree of tenacity. |
|---|---|---|---|---|
| | | *Bergman.* | *Wedgwood.* | |
| Platina | 21,000 | | | |
| Gold | 19,640 | 1031 | 5237 | 500 |
| Silver | 10,552 | 1000 | 4717 | 270 |
| Quickfilver | 14,110 | 40 | 40 | |
| Lead | 11,352 | 595 | | $29\frac{1}{4}$ |
| Copper | 8,876 | 1450 | 4587 | $299\frac{1}{2}$ |
| Iron | 7,80 | 1601 | 17977 | 450 |
| Tin | 7,264 | 415 | | $49\frac{1}{2}$ |
| Bifmuth | 9,670 | 494 | | |
| Nickel (pure) | 9,000 | 1061 | | |
| Arfenic | 8,308 | | | |
| Cobalt (pure) | 7,700 | 1601 | | |
| Zinc | 6,862 | 699 | | |
| Antimony | 6,860 | 809 | | |
| Manganefe | 6,850 | very great | | |

The power exhibited by the metals in *conducting heat* is, according to a tolerable accurate experiment made by Dr. *Ingenhouss*, with an apparatus invented by Dr. *Franklin*, in the following order: *Silver, Copper, Gold, Tin, Iron, Steel, Lead.* Having repeated the experiment twelve times, he found fome fmall variation in this feries; though filver conftantly appeared to be the readieft, and lead the floweft conductor of heat. [E]

CHAP.

# CHAP. V.

## ZYMOTECHNY; or, the CHEMISTRY of Fermenting Bodies.

OF the general principles of *Fermentation* which have already been laid down in the firſt part of this Work, I ſhall only repeat in as brief and ſuccinct a manner as poſſible, that *fermentation* conſiſts of a viſible internal motion of a fluid body, which tends to the ſeparation of that body's different heterogeneous parts; in which operation, conſequently, the whole of its compoſition is deſtroyed, neither can the body be reproduced from the parts ſo ſeparated. Of *Fermentation* three different kinds are diſtinguiſhed, referring to the different products which it yields, though, properly ſpeaking, there is but one kind of fermentation. *Fermentation* therefore is either of the ſpirituous, acid, or putrid kind. The product of the two former are the chief object of the art of making *wine* and *vinegar*; of that of *brewing*, and of the *diſtillation* of *ſpirits*. Beſides theſe, though in a more diſtant manner, there are ſeveral other occupations and arts connected with it*.

The product of the *ſpirituous* fermentation poſſeſſes an intoxicating property in conſequence of the ardent ſpirit which it contains, and which during the fermentation is developed and ſet at liberty from the compoſition of the bodies ſubjected to it. This ſpirit cannot be produced without the operation here alluded to; becauſe none of the other methods of ſeparation in uſe among the Chemiſts are

* *Fermentation* (taken in the ſtricteſt acceptation of the word) is the mutual action of ſugar on water, and water on ſugar; by which, in a certain degree of heat, they decompoſe each other, and form the *acetous* acid.

If the fermenting body contains a ſufficient quantity of ſugar and is united with a certain proportion of water, a liquor called *wine* is produced, which in diſtillation yields *ardent ſpirit*. The heat in which this proceſs takes place, is perhaps between the 50th and 100th degree of Fahrenheit. [E]

adapted

adapted to its volatile nature; they are befides too violent, infomuch, that by thefe means it would be rather diffipated and difperfed in the air, if not abfolutely decompofed and deftroyed.

The following fubftances from the vegetable kingdom, before all others, yield a produce of this kind. Apples, pears, plumbs, cherries, grapes, rafpberries, ftrawberries, and all fruits of a fimilar nature, which are the produce of other countries and parts of the world: farther, all kinds of corn without diftinction; as wheat and its different fpecies, rye, barley, oats, and other fimilar farinaceous feeds; likewife all fweetifh roots, as fkirrets, turnips, beet-roots, carrots, potatoes, Jerufalem-artichokes and other vegetables of this kind, as well exotic as indigenous. Even milk has been found not ill-adapted to this purpofe. But the liquor obtained from thefe fubftances by fermentation may, according to their refpective natures and elementary compofition, be made to produce either wine, beer or brandy.

The expreffed juices of all the abovementioned fruits after fermentation, yield a fpirituous beverage called *Wine*, which is diftinguifhed by fewer mucilaginous particles, and a greater quantity of real fpirit from *Beer*, which latter is obtained from farinaceous grains, and contains more mucilage and lefs fpirit. From thefe *Brandy* is diftinguifhed by its confifting of an aqueous fpirit, and being entirely free from thofe groffer mucilaginous particles.

For the purpofe of making wine, grapes chiefly are ufed; and next to them, all the abovementioned fucculent fruits. The preparation of this liquor was known already to the moft ancient inhabitants of the earth, though perhaps the procefs might not be conducted in the moft artificial manner. The good quality of wine depends chiefly on the goodnefs of its *growth* (as it is called) or on the natural mixture of the elements compofing the juice of the grape; for it is a fact that grapes do not thrive equally well in every place and every foil. Next to this, the quality of the wine farther depends on the degree of fermentation to which it has been fubjected. Accordingly as the fermentation has been more or lefs perfect, wines are diftinguifhed into *acidulous*, *fparkling*, and *fweet* wines, and are either of a *white* or *red* colour.

The firft operation is the *Preffing*; in performing which, the acid juice contained in the kernels, hulls and ftalks of the grapes, fhould be avoided; and therefore the produce of the laft preffings muft not be mixed with that of the firft.

The

The juice we ſpeak of is called *Muſt*; it ſoon begins to ferment, and therefore ought to be conveyed as ſpeedily as poſſible into a cellar in clean caſks, which muſt remain open till the fermentation is quite finiſhed, and the wine is become clear; after which it is ſuffered to remain upon its lees cloſe ſtopped up for five or ſix months, in order that the fermentation which, though almoſt imperceptible, ſtill exiſts, may go on without the loſs of the inflammable ſpirit. In the ſubſequent ſpring the wine is transferred into freſh caſks which have been previouſly fired on the inſide, when they are bunged up tight, and kept conſtantly full, during which time an almoſt imperceptible fermentation and ſeparation ſtill continue. As this fermentation is ſtronger in the firſt than in the following years, the wine ought therefore to be ſhifted ſeveral times during the firſt and ſecond year, but only once in the third year, till in conſequence of its becoming quite clear, this transfuſion is found to be no longer requiſite. In ſhort, the whole preparation of wine depends upon the natural, ſpontaneous and ſlow ſeparation of the groſſer parts, and upon the volatile inflammable ſpirit being carefully retained in its combination with the remaining acido-mucilaginous mixture, as alſo upon the prevention of a farther evolution of the acid from this ſame mixture.

All wines for the firſt two or three years have a ſomewhat acidulous taſte, occaſioned by the eſſential ſalt of the juice of the grapes, which ſalt ſeparates from it by degrees in proportion as a portion of the aqueous part of the wine evaporates through the ſubſtances of the caſks. It adheres to the interior ſurface of theſe caſks, and is known by the name of *Tartar*. It is not till after this ſalt is perfectly ſeparated from them, that wines acquire that mild taſte and increaſe of ſtrength which renders them ſo univerſally acceptable.

Whenever wine is transferred into a freſh caſk, the caſk ought to be fumigated; in the caſe of white wines, this is effected by ſetting fire to brimſtone on the inſide of them; but in that of red wines, with nutmeg or ſome other aromatic ſubſtance, or elſe with ſpirit of wine. Experience has ſhewn the neceſſity of this operation, though I muſt confeſs that I can ſee no other reaſon for it, than that by this means a muſty and putreſcent air, with which the caſk may chance to be filled, is expelled from it; while, on the other hand, the whole vacuum is filled up with a freſh inelaſtic aeriform fluid, which from its peculiar nature may prevent a fermentation taking place.

The *Sparkling* wines are obtained by taking new wines, not more than one

year

year old, which have been well fined down and racked off, and bottling them off, taking care at the ſame time to cork them very tight; a proceſs of which we have an inſtance in Champaigne wine. Here it is the interrupted fermentation, or rather the air, that is not perfectly developed, which produces the effect that follows upon opening the bottle again.

The *Sweet Italian*, and other ſimilar wines, are obtained in conſequence of a very imperfect and ſuppreſſed fermentation, and of the clarification of them, and ſeparation of the lees by mere dint of art; whence too they retain their natural ſweetneſs entire and unimpaired.

From fruit of a bad growth a better ſort of wine may be obtained, by juſt breaking the ſtalks of the ripe grapes at the uſual time of the vintage, and leaving them to hang on the vines till they are ſomewhat withered. The ſame effect is produced by taking muſt of a bad quality and boiling it down a little immediately after it comes from the preſs, or by freezing ſuch weak liquors as are already converted into wine, and drawing off from the ice the liquor that remains unfrozen.

The *Red Wines* have not their colour from nature, but acquire it in conſequence of the black grapes being bruiſed, and put, together with their hulls, into a vat to ferment. In this fermentation, the juice extracts the red colouring particles contained in the hulls. After the fermentation the wine is drawn off from the vat, and is called *vat-muſt*; the reſiduum is put into the preſs, but the firſt runnings only are mixed with what came out of the vat; the latter, which are of an inferior quality, being kept ſeparate.

The operation of *Fining* or *Clarifying* wines, is applied to the purpoſe of making turbid wines clear, and to that of ſeparating the fine floating lees, in order by this means to prevent the farther fermentation of the liquor. This end is anſwered by glutinous and mucilaginous ſubſtances, ſuch as iſinglaſs, hartſhorn-jelly, the whites of eggs, milk, gum-arabic, &c. The former of theſe is moſt commonly uſed. To each awm of wine (containing eighteen gallons) is uſually taken half an ounce of iſinglaſs, which, after being cut very ſmall, is diſſolved by boiling it in one pound of water over a moderate fire, ſtirring it continually, and is then ſtrained through a clean cloth. This jelly is immediately mixed, while it is yet hot, with ſeveral quarts of the wine, and beaten up with them till it froths, and then poured on to the reſt of the wine, together with which it is ſhaken or ſtirred for the ſpace of half an hour. After this may be added half an ounce of cream

of

of tartar in powder, together with a quarter of an ounce of ſalt of tartar. Theſe ſalts may in many caſes be very well diſpenſed with. The caſk is then bunged up, and the wine ſuffered to ſtand till it becomes clear, when it is drawn off and bottled. Red wines are fined down with the white of eggs, which muſt be previouſly beaten up well, till they froth. In theſe caſes too, fixed air may be introduced into the wine with very good effect.

The *reſtoration* of pricked and the *melioration* of ſour wines is effected in the ſame manner as a *poor* and *watery wine* is changed into a good ſpirituous and ſtrong-bodied liquor. The cauſe of theſe defects lies in the proportion of the natural conſtituent parts of the whole mixt, in conſequence of which the aqueous and acid part prodominating either naturally or through neglect, the wines are deficient in genuine ſpirit. To remedy theſe defects of the inferior ſorts of wines, and raiſe the liquor to the ſtandard of the more generous wines, either the part which is deficient muſt be reſtored by art, or that which is redundant, abſtracted. With a view to the former object, they muſt be charged with a larger portion of a homogeneous ſaccharino-mucilaginous ſubſtance, in which a conſiderable quantity of vinous ſpirit is contained in a latent ſtate*, and with which it muſt be made to ferment afreſh, in conſequence of which a different proportion of their conſtituent parts is produced. This end is attained in the following manner: Firſt, ten pounds of lump ſugar, broken into ſmall pieces, and fifteen of freſh Spaniſh raiſins, without either ſtalks or ſtones, are put into a clean and ſweet caſk; upon which the caſk is filled about three quarters full with wine, and the bung is put in very ſlightly. During the firſt five days the caſk is ſhaken twice a-day, and in order to promote the fermentation of the liquor, ſixty drops of ſpirit of vitriol and one hundred drops of a ſolution of ſalt of tartar in water are added to it, each ſeparately, care being taken however after the addition of the former ingredients, to ſhake the caſk well before the latter is poured in. If, after ten or twelve days are elapſed, the wine does not begin to ferment, the fourth part of each of theſe ingredients may again be added, and the liquor let alone for three or four days longer. If the fermentation does not then enſue, the fourth part of the ſame ingredients may be added once more. The caſk in the winter time ſhould be kept in a tolerably warm room, but in the ſummer in ſome convenient warm place in the open air. The whole fermentation ought to laſt forty days in all; but if it ſhould ceaſe ſooner, it may be excited again by dropping into it alternately a ſmall quantity

* Or rather, which is capable of producing a conſiderable quantity of vinous ſpirit. [E]

 of

of the liquors before mentioned. When, during the fermentation, the wine grows bitter, it is a good ſign.

The wine having fermented for the ſpace of forty days, the caſk is carried into the cellar, and ſuffered to ſtand there undiſturbed, till the lees have ſubſided to the bottom, and the liquor is become clear. After this it is transferred into a freſh caſk, that is fumigated with ſulphur, when it is treated like other wine. Its clarification may alſo be promoted by fining it down. When the wine is wanted to reſemble ſack, the caſk is ſtrongly fumigated with nutmegs. The whole proceſs takes up from ſix to eight weeks.

After the following methods the German wines may be endued with ſome of the *properties of foreign wines*. This is improperly termed a tranſmutation of the wines; as, in fact, it is nothing more than an *artificial aſſimilation*.

For imitating *Burgundy*, one part of the frozen muſt of red wine muſt be mixed with three of red wine itſelf, in like manner concentrated by froſt, and the whole mixture fermented and ſuffered to ſtand till it is two years old; if there is neither red muſt nor red wine to be had, white will anſwer the purpoſe, if in the firſt ſummer, a tenth part of the juice of black cherries, from which the ſtones have been taken before they were preſſed, be added to it, and the wine be ſuffered to ſtand untouched for the ſpace of two years.

The following wine will reſemble the fineſt ſparkling *Champaigne*: Take of the muſt of wine, concentrated by froſt, one part, and mix it with three parts of wine, the ſtrength of which has been increaſed by the ſame means, and, as ſoon as it becomes clear in the caſk, draw it off into bottles.

The *Italian* wines are imitated, by letting three parts of frozen muſt ferment with one part of wine, in like manner concentrated by froſt, and leaving the liquor to fine itſelf in the caſk.

The following wine is a good imitation of *Rheniſh*: Take any quantity of wine, tolerably new; let it freeze but once; and afterwards, as often as it becomes fine, rack it off into another caſk, and take care not to drink it till it is three years old. But if the wine be very acid, a ſixth part of concentrated muſt ſhould be added to it, which will correct it, and render it ſoon fit to drink.

*Spaniſh* wines are the half fermented and clarified muſt of very ripe grapes. The grapes therefore muſt be ſuffered to wither, and the juice be preſſed out of them in very cold weather, and ſuffered to freeze very intenſely, and afterwards be left to fine itſelf in the caſk.

The

The following wine is in imitation of the wine called *Stein-wine* *. Mix one part of muſt, concentrated by freezing, with two parts of wine which has twice undergone this operation, and let it ſtand a whole year in the caſk.

*Hungarian* wine is imitated by mixing together equal quantities of muſt and wine, both of which have been concentrated by froſt, and letting them ſtand for ſeveral years. This liquor acquires additional ſtrength, in caſe the wine which is mixed with the muſt has been ſuffered to freeze twice.

By ſuch innocent arts may ſour and unwholeſome wines, which, from the nature of their compoſition in conſequence of the deficiency of ſpirituous and of the redundancy of aqueous and acid parts are not even readily brought to ferment, be very eaſily meliorated and enhanced in value. But every abuſe of this practice is highly blameable, and a wine thus meliorated and improved ought only to be ſold for what it really is; and even though ſome unſkilful purchaſer ſhould take it for wine of a foreign growth, ſtill it would be an act of diſhoneſty to ſell him ſuch wine by an appellation to which it had no juſt title, and to take his money upon the ſtrength of ſuch prepoſſeſſion. We ought therefore to be contented with having, according to art, changed a wine which was otherwiſe not fit to drink, into a pleaſant and wholeſome beverage.

But criminal in the higheſt degree is the practice of rendering crude and ſour wines ſweet with calces of lead; all of which are abſolute poiſons, A few drops of a ſolution of liver of ſulphur, added to a glaſs of wine, diſcover this noxious impoſition, either by a brown or black colour. As this colour however may alſo chance to proceed from ſome other cauſe, the affair muſt whenever there ariſes a ſuſpicion of this kind, be ſet in a clearer light, and the lead contained either in the brown powder depoſited by a more conſiderable quantity of the wine, or in a precipitate made with alkali, reduced to its perfect metallic ſtate by means of tartar †.

*Fruit*

* *Stein-wein* is a peculiar ſpecies of Neckar wine, which grows in the country near Wurtzburgh, and is reſerved for the Biſhop of Wurtzburgh's table. [E]

† The firſt traces of this horrid ſophiſtication are to be found in the beginning of the ſeventeenth century. Profeſſor *Beckmann*, in his *Contributions to the hiſtory of Invention*, Part II, No. 3, has cited the remarkable paſſage which proves this point, and is contained in *Pirckheimeri Opera*, Francof. 1610, p. 136. A Bavarian friar, of the name of *Martin*, who, perhaps by reaſon of his ignorance, was not aware of the danger of his art, is ſaid to have been the infamous inventor of this arcanum. It was not till the beginning of this century that the means of detecting



this

*Fruit wines* differ from each other as much as the fruits do of which they are made. The moſt celebrated of them is *Cyder*, which in many countries is made of acidulous apples in great quantity. Beſides theſe other fruits, in ſo far as they are to be had in ſufficient plenty and tolerably cheap, may alſo be uſed for the purpoſe of making wine. Such are *pears*, *currants*, *ſtrawberries*, *raſpberries*, &c. The beſt uſe likewiſe that can be made of natural wines of an inferior quality is to make *artificial* wines with them of various ſorts, by mixing them, and cauſing them to undergo a freſh fermentation with the juices of the ſweeter fruits, ſuch as cherries, plums, and the like, at the ſame time adding a ſmall quantity of ſpices.

The firſt thing to be obſerved with reſpect to cyder is, that the apples muſt be piled up together, in a place expoſed to the open air and ſun, in order that the juice of them may firſt be perfectly well matured; after this they are to be carried up into an airy loft or garret, that the ſuperfluous humidity may evaporate.

In the operation of preſſing them off, care muſt be taken in like manner as in the caſe of grapes, that the rinds and kernels be not maſhed and preſſed overmuch, by which means the cyder is apt to acquire a rough and bitter taſte. A better method therefore of preſſing or grinding them than that at preſent practiſed at preſent, is a deſideratum of the greateſt conſequence.

As to the magagement of the fermentation, every thing that has been already obſerved with reſpect wine holds good here alſo. Cleanlineſs, the avoiding of the loſs of the ardent ſpirit, the ablation of theſeparated recrementitious parts, and the fining muſt conſtitute the chief objects of the operator's attention in this proceſs. The muſt of fruit may alſo be divided into two equal parts; and one part of it boiled down to half the quantity, and left to ferment in conjunction with the remainder; or ſome of the ſweet liquors before mentioned may be added to it, previous to the fermentation. Both the muſt and the wines of made-fruit may likewiſe be meliorated by concentration them by means of froſt.

this fraud was diſcovered. Vid. *Zelleri* Diſſ. de docimaſia Vini-lithargyrio mangonizati. Tubingæ, 1707. The artificial liquor employed for this purpoſe, has been deſcribed above two hundred years ago, by *Alexius Pedemontanus*; but according to *Peter Borelli*, Hiſtoria et obſervat. Medico-phyſ. Cent. IV. Paris 1653, was chiefly known as an aqua magnetica e longinquo agens, or as a ſympathetic ink. From the effect it had in this latter reſpect, the application of it to the abovementioned purpoſe was obvious. [A]

Hither

Hither alſo may be referred the coarſer ſorts of wines, ſuch as *mead*, a *mixture of ſugar and water*, and the *juice of the birch-tree*. For *mead*, honey is diſſolved by being boiled up together with five or ſix times its quantity of water, and continually ſkimmed. During the boiling too a quantity ad libitum of hops, tied up in a cloth, may be put into the liquor; which after this is transferred into a caſk, and when it is ſufficiently cool, mixed with a ſmall quantity of good yeaſt, and left to ferment properly. For making the Lithuanian mead, it is ſaid, that inſtead of water, the honey is diſſolved in the juice of birch, and that it is to this circumſtance that the liquor owes its peculiar excellence. The ſame proceſs may be uſed for a mixture of ſugar and water, as alſo for the juice of the ſugar-cane alone, and in like manner for the mere juice of the birch-tree, and all other ſweetiſh liquors extracted from vegetables.

In all the caſes above-mentioned the obſervation holds good, that the more ſweetneſs and the leſs water theſe juices have till they arrive at a certain degree of fluidity, the more are they inclined to fermentation, and the leſs do they ſtand in need of any additions in order to throw them into this ſtate. But when the oppoſite circumſtances take place, freſh wine, inſpiſſated muſt, raiſins or ſugar, may ſerve, with the aſſiſtance of a gentle heat, to promote this proceſs.

We now come to the ſecond kind of ſpirituous liquors, which are diſtinguiſhed from the former by a larger portion of mucilaginous matter, and are for this reaſon the more nutritious. Theſe are the different kinds of *Beers*, which after undergoing a certain preparation, are obtained from various ſorts of corn, but chiefly from wheat, Indian-corn, barley and oats, by decoction and fermentation. At the ſame time, in order to deſtroy the nauſeous ſweetiſh taſte of this decoction, and likewiſe to enable it to keep the longer, it is cuſtomary to boil up along with it a certain quantity of hops. Theſe liquors are chiefly diſtributed into two grand claſſes, viz. the *brown* and the *white* beers.

The *preparation* of the above-mentioned kinds of corn conſiſts in *malting them*. For this purpoſe, the grains are firſt ſteeped in water, which in proportion to the heat of the weather is more or leſs frequently drawn off, and freſh water added till the grains are become ſo ſoft that they may be bent with the finger, without breaking. Upon this, the grains thus ſteeped, after the water has been drawn off from them, are piled up on the clear floor of a cellar, in heaps of an equal ſize, in order to give the radicles an opportunity of ſprouting; in which operation, however, the ſhooting of the real germs, which are placed oppoſite to them, muſt be carefully avoided. For this end, the heaps muſt be frequently

ſpread

ſpread abroad, and the grains well rubbed. The malt is then without delay either ſpread out very thinly upon the floor, in large roomy lofts, or elſe dried in kilns conſtructed for the purpoſe; during which operation it is frequently turned.

The intent of this preparatory proceſs is, by means of the water, attracted by the farinaceous part of the grain, to effect in the ſoluble mucilaginous compound reſident in it, an incipient ſeparation adapted to its nature, and to render the grain more ſpongy and porous than it was before. The good ſucceſs of this operation is diſcovered by a ſweetiſh taſte. In order to obtain this ſweetiſh mucilaginous compound, great care ſhould be taken that it be not deſtroyed either in the operation of ſteeping, or in that of drying; becauſe in it, in fact, are enveloped as it were, all the ſweetneſs and ſpirit of the whole fermenting mixture. This beginning evolution however ought to be checked again at the proper time, and that with ſufficient ſpeed, for which purpoſe the operation of drying is requiſite.

The malt when perfectly well dryed, and fit for uſe, is freed from its radicles by rubbing and threſhing, and after being ground in a mill, is ſcalded with hot water, and then boiled in order to extract the ſoluble ſweetiſh mucilaginous compound. This decoction is called the *Maſh*, or *raw Wort*. Then a certain quantity of hops is either ſcalded only, or elſe boiled, (according to the particular cuſtom of each place), ſometimes with plain water, and ſometimes with the ſecond decoction of the malt, (juſt as the cuſtom is where it is made); and this decoction, which known by the name of *boiled Wort*, is mixed with the former.

The hops are added, partly in order that the ſweet maſh may be enabled by the aromatic bitter quality of theſe plants, to keep the longer, and to prevent it from paſſing over too rapidly to the acid fermentation; partly with a view to deprive the beer of the nauſeous ſweet taſte it would otherwiſe have, and partly alſo that it may be rendered wholeſomer and leſs flatulent. Inſtead of hops, other aromatic plants might alſo be uſed for the ſame purpoſe.

But as beer boiled down in this manner conſtitutes an attenuated mucilaginous liquor, containing all ſorts of groſs farinaceous particles, it has this defect, that it cannot be kept long in this ſtate, but eaſily turns ſour, and even mothery at laſt. For this reaſon it muſt be cooled ſpeedily; becauſe a long-continued heat promotes this defect; and muſt be farther converted by *fermentation* into a durable and pleaſant beverage. With this view the attention of the operator ought to be chiefly directed towards the two following points. Firſt, that the beer be cooled

cooled down to the proper degree of heat: fecondly, that the yeaft be added in a fufficient quantity, but not exceeding a certain proportion. As the degree of heat is not the fame at all feafons of the year, it cannot be abfolutely determined; befides, the temperature of the climate fhould be taken into confideration in this operation. Neither can the quantity of yeaft to be added, be determined in a general manner; but muft be inferred from experience; as in this cafe, the fituation of the brewery, the condition of the cafks, the nature of the water and air, have a great influence. The intention is to prepare of the fweet mucilaginous decoction of the malt and hops, a pure, metallic, vinous and wholefome beverage, that fhall be capable of being kept for a certain time. For this purpofe, the vifcofity of the compound muft be broken, the groffer parts feparated, and the inflammable fpirit enveloped in it, but fet at liberty and rendered obvious to the fenfes; and this is effected by means of an adequately flow evolution during the fermentation, for which, according to the different circumftances, the hundredth or three hundredth part of yeaft is requifite. At each particular place it is fafeft to determine the proportion by experience, on which occafion the following circumftances ought to be attend to: When beer has a fweet and naufeous or a barmy tafte, when it has a turbid appearance, and foon turns mothery; the quantity of the yeaftwas too fmall. Flat beer is the fign either of a hurried or elfe an imperfect fermentation; chiefly of the want of ardent fpirit, which is, in fact, the balm which preferves it from being fpoiled; in this cafe the quantity of yeaft muft be increafed. But when beer expands much in fining, and cannot well be kept in clofe veffels, then this fhews that the yeaft has been employed in too great quantity. Upon the whole, we ought to confider that in the fermentation of beer, it is not the whole mixture of the fweetifh mucilaginous compound which is to be developed, and that it is not all the fpirit which is contained in it, that muft be extricated from the body with which it is originally combined; in which cafe indeed an exceedingly intoxicating, but, on the other hand, rather acid and not very agreeable beverage, would be obtained; but this developement ought to take place in a particular part of it only; the reft ftill remaining in its primitive mixture, that a portion of the fweetifh and nutritious matter may likewife be retained; and that confequently a fpirituous and vinous, but at the fame time alfo a pleafant, wholefome, and nourifhing beverage, may be produced.

The white beers, which are known by the name of *Broyhan*, after a brewer called *Cort Broyhan*, of Stocken near Hanover, who cafually invented thefe

kinds

kinds of beer, and died in the year 1570, are prepared of the malt either of wheat or barley, dried in the open air, with the addition of a ſmall quantity of hops. Hence they are of a whitiſh colour and a ſweetiſh taſte, and are likewiſe commonly more flatulent than the brown beers. *Bottled-beer*, with reſpect to the different ſorts of beer, is what Champaigne-wine is with relation to the various kinds of wine. It is obtained by drawing off new beer after it has undergone a very briſk fermentation, into ſtrong bottles very well corked, and keeping it for a conſiderable time. The *Herb* beers are ſufficiently deſcribed by their names, and obtained by fermenting different bitter, or aromatic herbs, with new beer juſt barrelled, and by this means impart to them their taſte, ſmell, and other properties.

The chief circumſtances to be attended to in keeping beer, are to expoſe it as little as poſſible to air and heat. To this end, the caſks muſt be pitched over in the inſide, and the bung ſtopped down cloſe, which may alſo be covered with pitch; and further, the caſks ſhould be kept in the deepeſt and cooleſt cellars that can be procured.

The *Diſtiller's* buſineſs is different from the preceding, and conſiſts of a perfect and total evolution (by means of fermentation) of the acido-ſaline mucilaginous compound contained in corn, fruit and other bodies, adapted to this operation, that all the ardent ſpirit contained in them, may be burnt out from the original natural combination as affected by nature, and in the ſubſequent ſeparation of it by means of diſtillation. Upon the difference of the bodies uſed for this purpoſe, and their elementary compoſition, depends the good quality of the ardent ſpirit which is to be obtained from them.

*Genuine Spirits of Wine*, otherwiſe called *Brandy*, in thoſe countries where there is much wine cultivated, is extracted without uſing any good and drinkable wine for this purpoſe, from the lees of wine and the huſks of grapes, of which the *French* and *Rheniſh Brandies* may ſerve as inſtances.

For want of a ſufficient quantity of it, and on account of the high price it bears in many countries, theſe ſpirits are extracted from rye, and hence called *Malt Spirits*. Though many other ſubſtances* are fit for this purpoſe, and ſeveral

* M. *Hoffman*, of Leer in Eaſt-Frieſland, took ſix pounds of the freſh roots of couch, or dog's-graſs, and after cutting them in pieces and bruiſing them, made a maſh of them with boiling water. This he fermented with two ounces of yeaſt, and when the fermentation was finiſhed, put the liquor into an alembic, and drew off a watery ſpirit from it, which after being rectified, produced four ounces of a liquor as ſtrong as common malt ſpirit, and of a much more agreeable flavour. He

ſeveral of them even yield a ſomewhat greater quantity of ſpirit, rye is notwithſtanding the kind of corn moſt uſually employed in this intention; as it is cultivated in the greateſt quantity and even to ſuperfluity; and, conſequently, both on account of the produce it yields, and its price, it is always more advantageouſly uſed than any other kind of corn. Otherwiſe wheat, barley, and oats, may be alſo applied to this purpoſe; of theſe the former is ſaid to yield one third more ſpirit than rye.

For the purpoſe we are ſpeaking of, the rye is uſually ground with a ſixth part of barley malt, and afterwards ſcalded with hot water, by which means the ſoluble ſweetiſh mucilaginous compound is extracted. This being done, the mixture is cooled with cold water to that degree, that the yeaſt may now be immediately added. After this has been ſtirred in among it, the vat that holds the fermenting mixture is to be covered with a lid, in which there is only one ſmall aperture, beſides which, cloths are laid over it in the winter, in order to retain the gentle heat requiſite for carrying on the fermentation; and in this manner it is left to ferment by itſelf, till the fermentation is finiſhed. The moſt certain ſign of the termination of this proceſs is, when after forty or perhaps forty-eight hours, no more bubbles are ſeen to riſe, nor hiſſing noiſe perceived, and the mixture, which before had riſen remarkably, has ſubſided again, in which caſe it is no matter whether the liquor be clear or not.

Immediately upon theſe appearances, the operator muſt proceed to diſtillation. In this operation, particular care muſt be taken that the mixture do not adhere to the bottom of the ſtill, and contract an empyreuma, a circumſtance from which the diſtilled ſpirit is apt to acquire a bad ſmell and taſte; farther, that

He therefore with great juſtice recommends this weed, which may be had, if not for nothing, at leaſt for the expence of digging it out of the ground, to the notice of the diſtillers, as a decoction of it may ſerve for cooling their maſh, and thus greatly increaſing the quantity of their ſpirit. Of a decoction of theſe roots with a little yeaſt and hops, he likewiſe made a tolerably palatable beer, which kept good for three months. Perhaps treacle in the proportion of half a pound to a gallon, would be no uſeleſs addition. A compoſition of this kind too might ſerve for making vinegar, equal in goodneſs to the common malt vinegar uſed in this country, and 100 per cent. cheaper. This root which is now only uſed for manure, for which purpoſe it is burned, contains a large quantity of Saccharine matter. From three ounces of the expreſſed juice, M. *Hoffman* obtained two drachms and thirty-three grains of fine cryſtallized Saccharine acid. In ſome parts of Sweden, in a ſcarcity of corn, they make theſe roots into bread. [E]

3 Q during

during the diſtillation the ſpirit do not evaporate away, in order to prevent which, the fire muſt be regulated with caution, the veſſels well luted together, and the water in the cooler often renewed and thus kept continually cool; and laſtly, that the liquor which comes over, no longer exhibits any veſtige of an ardent ſpirit.

What comes over in this diſtillation is an ill-taſted watery ſpirit, which therefore muſt be *rectified*, i. e. deprived of its ſuperfluous water and its diſagreeable flavour, by a freſh diſtillation. In this operation, for the ſake of purifying the ſpirit ſtill more, ſome clean wood-aſhes may be thrown into the rectifying ſtill, with a view the better to retain in it the nauſeous acid, which paſſed over in the firſt diſtillation along with the ſpirit, and is impregnated with particular ethereal particles. At the ſame time too various aromatic additions may be put into the ſtill, in caſe the ſpirits are to be impregnated with them. A ſtop is put to this ſecond diſtillation, as ſoon as ever the liquor that paſſes over begins to manifeſt a watery taſte.

As long as chemiſts continued to entertain the chimerical notion, that the inflammable ſpirit was not inherent in the fermenting ſubſtance, but was generated from certain conſtituent parts of it, during the fermentation; at the ſame time that it was obſerved that even after the abſtraction of the ſpirit a great quantity of theſe imaginary parts, ſuch as acid, water and inflammable matter, remained behind in the ſtill; they were continually deviſing various ſchemes by which the meaſure of ſpirits obtained from a certain determinate quantity of corn might be encreaſed. They conſtantly failed however in their attempts. In fact, they were deceived by the circumſtance, that at ſome times more ſpirit was obtained than at other times, owing to the greater or leſs precaution they had taken in the operation; or elſe from their not having been aware of the difference in the weather. But the truth is, that when by paying due attention to the fermentation and diſtillation, all the ſpirit is obtained which exiſts in the bodies, all has been done that the art is capable of doing. But on the other hand, that a buſhel of rye, for inſtance, when the mucilaginous part of it is extracted by the juice of birch-tree, or by ſugar, or by honey and water, muſt yield more ſpirit than when the ſame part is extracted from it by water alone, is a fact, that ſpeaks for itſelf.

Upon the ſame principles, likewiſe, ardent ſpirits may be obtained from other kinds of vegetables and parts of vegetables, beſides the different ſpecies of corn, for example, from *carrots*, *potatoes*, and ſimilar farinaceous plants; from *cherries*

in

in the Swiſs manner, and from the Siberian baſtard *cows parſnep*, in the method practiſed by the inhabitants of Kamſchatka. Of *melaſſes* and *ſugar* is made *Rum*, which in ſome countries is known by the name of *Taffia*; and from *rice* and the juice of the *palm-tree*, *Arack* is prepared. The Tartars are accuſtomed to make their brandy of mare's-milk, and call it in their language, *Koumyſs* *. This latter fact, though ſome prejudiced perſons have gone ſo far as to deny it, is now proved beyond all doubt, and has lately been confirmed by the experiments of Profeſſor *Spielmann*. Wine and brandy may be obtained from all cows milk, provided the ſeparation of the milk be prevented by frequent and continued agitation. Thus, for inſtance, a quantity of milk may be put into a glaſs phial with a narrow mouth, and ſhaken frequently for the ſpace of a fortnight. At

* Dr. *Grieve* in the Edinburgh Tranſactions, Vol. I, has ſtrongly recommended Koumyſs or mare's-milk in conſumptive diſorders: but, although there ſeems to be more ardent ſpirit in mare's than in cow's milk, yet we apprehend, that, upon the whole, the vinous liquor produced by the latter will be found not at all inferior to the former; and therefore ſtrongly recommends it to be taken in hectic fevers, ſcorbutic cachexies, atrophies and other ſimilar complaints, as a ſuccedaneum for the Koumyſs of mare's milk, which in this country can hardly, if at all, be procured.—In all probability butter-milk in ſome meaſure owes its celebrity in conſumptive caſes to its being partly in the vinous ſtate. [E]

* It has been frequently aſſerted that reſt is a neceſſary condition to fermentation; and indeed, this has been the grand objection to *Sydenham*'s doctrine of fevers, which, according to him and other phyſicians of thoſe times, proceed from a fermentation excited in the blood, which being continually put in motion by the action of the heart, it is impoſſible, ſay his antagoniſts, for the motion of fermentation to take place in it: but here we have an inſtance of fermentation, in which not only reſt is not requiſite, but in which it is even prejudicial to the proceſs. In milk, the agitation is ſaid by Dr. *Grieve* in the Edinburgh Tranſactions, to be requiſite, in order to prevent the ſeparation of the fixed air, and to mix this acid vapour with the other conſtituent parts: but this is hardly the caſe; this acid gas, as our author obſerves, being ſeparated in great quantities, particularly when there is no ſeparation of the butyraceous part. On the contrary, the true intent of the agitation evidently appears to be, to bring the butyraceous part into contact with the reſt of the liquor, (from which, in conſequence of the difference of its ſpecific gravity, it would otherwiſe ſeparate) and by this means to afford them an opportunity of decompoſing each other; when the inflammable gas of the oily part or butter unites with the other conſtituent parts of the milk, while the aerial acid is generated by the combination of the vegetable principle, which reſides chiefly in the caſeous part, with the pure air of the decompoſed ſerum or watery part, and as faſt as it is generated, flies off. Thus, by agitation, the vinous or firſt ſtage of the acetous fermentation is produced, which otherwiſe does not take place, the liquor paſſing over immediately to the acetous. [E]

firſt, the cream always ſeparates from the watery part; but by degrees unites perfectly with it. No increaſe of heat is obſerved in this operation; but, when the ſeparation ceaſes to take place, a very ſour ſmell is perceived, and a great quantity of air eſcapes, in conſequence of which too, the milk now begins to riſe, and would even burſt the veſſel, were it too cloſely confined*. When at length no more cream ariſes, and no more air is perceived to eſcape, the veſſel is ſtopped up cloſe, and ſuffered to ſtand undiſturbed for a fortnight longer, during which time the acid ſmell will go off by degrees, and change to a vinous odour. In conſequence of this treatment three ounces of vinous ſpirit, which, on being ſet fire to, burned away to one half, were obtained by diſtillation from ſix pounds of cows milk *.

All the ſubſtances before mentioned, when the fermentation has proceeded ſo far as to develope the ardent ſpirit, and is not checked by ſome means or other, now exhibit another phenomenon; viz. during the progreſs of the fermentation that is begun in them, another compoſition of their original mixture is attacked, and from this chiefly is developed an acid, which is known under the appellation of *vinegar*, and diſtinguiſhed by the different names of *wine- fruit- beer- brandy-* and *milk-vinegar*. Inaſmuch as this acid fermentation is preceded by the ſpirituous, in the bodies ſubjected to it, it might, upon the whole, be called the ſecond ſtage of fermentation; but again inaſmuch alſo as an acid fermentation may likewiſe take place, without having been preceded by the ſpirituous, in ſuch bodies as contain no vinous ſpirit, it is more properly conſidered as a fermentation of a particular kind.

When the above-mentioned fermented ſubſtances are to be converted into vinegar, they muſt be treated in a manner quite the reverſe from what they were before, as for this purpoſe the eſcape of the ardent ſpirit is requiſite. In order to produce *wine vinegar*, nothing more is neceſſary to be done than to put a quantity of bad wine, which is not fit for any other purpoſe, into caſks that have not been pitched on the inſide, leaving an empty ſpace in each of them equal to a hand's breadth, and to keep them with their bung-holes open in a warm place, till the wine is converted into vinegar, after which it is to be transferred into clean veſſels, which muſt be filled up quite to the top, and bunged up tight †.

For

* Vid. *Nicb. Oſeretſkowſky* Diſſert. de Spiritu ardente ex lacte bubulo. Argentor, 1778. [A]

† Dr. *Hahnemann* converted Miſnian wine into vinegar, by letting four ounces of it ſtand in contact with pure air for the ſpace of two months in between ſeventy and eighty degrees of Fahrenheit.

For the purpose of making *Fruit vinegar*, all kinds of fruits, both cultivated and wild, but chiefly apples and pears, are employed indiscriminately; but all the rotten and decayed fruit is previously picked out and thrown away. The sound fruit remaining is first ground in a mill, and afterwards pressed off, either by itself or with the addition of a quantity of water, and a cask is filled almost full with this juice. This, after it has fermented from four to six, or even eight weeks, with the bung out, and the internal motion is no longer perceptible in it, is drawn off from the lees, and put into fresh casks, which, as in the case of wine-vinegar, are filled within a hand's breadth only of the top; and are either left to stand in the cellar with the bungs out, or else taken into a warm place, to undergo the expected alteration.

Fahrenheit. The wine continued to be sound, till it had been exposed to the atmosphere twenty-four hours. When the bottle was opened, the air contained in it was converted into aerial acid. *Chemical Annals*, 1788, Vol. I. part 2.

It must here be observed, that although there is a regular gradation from one vegetable acid to another, in the order of their dephlogistication, and absorption of air; the tartaric acid being convertible into the oxaline; this into the melic; the melic into the acetous, and the acetous into the aerial, yet this order cannot be inverted by what may be stiled, a retrogade process; no one of these acids having as yet been changed into any of those here placed before it: for notwithstanding the assertions of M. *Amburger*, in the Chem. Annals, for 1787, Vol. II. page 498. it does not by any means appear that vinegar is convertible into the oxaline acid. He was probably deceived in the supposition that he had formed the oxaline acid of the vinegar he treated with nitrous acid, when in reality he only formed it of the vegetable principle existing as yet unacidified in the vinegar.

The concentrated acetous (or epoxycratic) acid is prepared by M. *Lorenzen* of Copenhagen, from eight ounces of sugar of lead and three of oil of vitriol. This proportion differs from Mr. *Dollfuss*'s, given above, at page 181; but that the vitriolic acid is in sufficient quantity, is evident from the circumstance, that when a few drops of a solution of barytes in distilled vinegar are added, no traces of the presence of vitriolic acid are perceptible. But what is of much greater importance, the absence of lead also in this liquor is demonstrated by the instillation of volatile liver of sulphur. Should at any time the smallest quantity of vitriolic acid be contained in it, by the addition of a few drops of the solution of barytes, just mentioned, it may be precipitated entirely in the form of heavy spar. M. *Lorenzen* asserts likewise that by distilling the acetous acid from verdigrise or sugar of lead, without the addition of vitriolic acid, a quantity of lead or copper always passes over into the receiver. Distilled, by means of the same acid, from vinegar saturated with either of the fixt alkalies, as recommended at page 181, by our author, the concentrated acetous acid, he alledges, has an empyreumatic odour, if the fire be strong; if weak, the acid obtained will likewise be weak, or the quantity small. Vid. *Beytrage* Zu den Annalen, Vol. III. part 1. [E]

For

For the purpofe of making *Alegar* or *beer Vinegar*, in the firft place a juice is extracted from corn, fimilar to that which nature produces in fruits. Confequently the procefs here is the fame as in the brewing of beer, except that in this there are no hops ufed at all. For this purpofe commonly equal parts of brown and pale barley-malt are ground, and made into a mafh with hot water, and a liquor extracted from them, to which yeaft is added. After the firft fermentation is over, the liquor is put into cafks that before have had either vinegar, wine, or melaffes in them, and which muft be kept, with the bungs out, in a room heated by means of fire in winter, and in fummer by the rays of the fun.

In this latter inftance the acidification proceeds flower, on account of the redundancy of the mucilaginous parts, whence acetous ferments of various forts muft be employed, in order to accelerate the procefs. The principal of them are as follows: Firft, a few quarts of good fruit-vinegar are to be repeatedly boiled with half a pound of tartar, when the whole is put into a cafk, along with the liquor to be fermented: fecondly, inftead of vinegar, a few pots even of new beer may be boiled up with a pound of pounded tartar, and poured into a cafk: or, thirdly, a loaf is made of good leaven, with the addition of an ounce or two of bruifed pepper, a handful of muftard frefh ground, or (which is better) fcraped horfe-radifh, and the fame quantity of falt, together with half a pound of pounded tartar, which loaf is afterwards thoroughly fteeped in ftrong vinegar: it likewife anfwers extremely well, to fteep it, at the fame time, in half a pint of malt fpirits, and to put it into the cafk by piece-meal. Fourthly, a quantity of the bare ftalks of raifins, or of frefh vine-leaves bruifed, or of grape ftalks ftripped of the fruit, are put into the liquor; or elfe, (which is ftill better) thefe ingredients are firft boiled up with a few quarts of new beer.

*Brandy-vinegar* bears the greateft refemblance to beer-vinegar, in one principal circumftance, which is, that it is produced from a farinaceous body, viz. rye. It is obtained either by lading out, after the thick part has fettled, fome of the clear part, of a completely well-fermented mixture, from which brandy is to be diftilled; or, by fuffering the wafh, that remains in the alembic after the brandy has been diftilled from it, to fettle thoroughly for fome days, and decanting the clear liquor; or, by diftilling feparately the phlegm that remains in the rectifying ftill, after the fpirit has been drawn over; or finally, by adding to this latter, an eighth part of the fermented wafh employed for making brandy, and then adding to either of thefe a good acetous ferment, and keeping it in an open veffel, and in a warm place.

*Vinegar*

*Vinegar of Milk* is obtained by keeping whey, with the addition of an acetous ferment, for a certain time in a gentle heat; and in general the change that takes place in fresh milk, and the separation of it into cream, and likewise the *turning* the whole and entire substance of sweet milk, after the manner of the Swiss, who make their cheese from it, ought each of them to be considered as an imperceptible kind of fermentation; and therefore in certain seasons of the year the separation of the butter, when it proves difficult, may be promoted by the addition of an acid.

The preparation of *Starch* (Amylum) is also commonly attended with a slight fermentation. It is chiefly made from wheat, this kind of corn containing the most and the whitest flour. For this purpose the wheat is to be washed, ground to groats, and macerated in cold water, till the fine farinaceous part begins to separate from the rest (viz. the glutinous part) of the wheat, and the bran, and renders the water milky. The groats are then to be put into a bag, and trodden, and this operation continued, repeatedly pouring fresh water upon them, till all the fine farina is extracted, and nothing left but the coarse hulls. After the fine flour, which has run through the bag, has settled at the bottom, it is then to be frequently covered with fresh water, and washed, with the view of carrying off all its smell, taste, and coarser particles; and lastly, it must be freed from all the water that adheres to it, by being put upon extended cloths, then broken to pieces and well dried; from which afterwards, by mere trituration, *Starch* and *Hair-powder* are obtained. By this maceration, and the gentle fermentation that takes place, the viscid and acido-saline particles are extracted, and the farinaceous parts divided into the smallest molecules, from which, the difference between starch and common wheat-flour, and the superiority of the former may easily be conceived. Just as great a difference also is there between this and the mere *Fecula* of potatoes, and other farinaceous roots, which may be obtained without either maceration or fermentation, by merely triturating them with water, and washing over the fine meal.

It is upon fermentation, likewise, that the main point depends in the making of the different kinds of *bread*, which may be divided in a general way into *white*, *brown*, and *sugared* bread, or *confectionary*. In these the general view is to render the dough, from whatever different kinds of flour it is made, porous and spongy, well tasted, and of easy digestion, (which is done by fermentation,) and afterwards by baking to make it fit for being kept for use. For making *confectionary*, starch

and

and fine wheaten flour are chiefly employed; together with ſugar, almonds pounded, and ſeveral other ingredients. Here, either the ſugar itſelf acts as the ferment, or the riſing of the dough is effected by the whites of eggs or a little purified alkali. From the ſame reaſon the requiſite raiſing of the dough in *honey-cakes*, is derived either from the honey, which is of itſelf inclined to fermentation; or it is promoted by the addition of ſome alkali. In the baking of *white bread*, the riſing of the dough made of wheat-flour is brought about by the addition of yeaſt. Here therefore is an incipient ſpirituous fermentation, which however muſt be checked in due time. But in the baking of *brown bread*, the acetous fermentation takes place; here rye-meal, by means of an acid leaven and hot water, is put into a ſtronger fermentation and kept longer in it. By this means the flour is made more porous and is more developed, and, by the evolution of the acid, rendered better taſted, more nouriſhing and fitter for keeping. Inſtead of the uſual leaven, ſour yeaſt may alſo be uſed; and even ſhould this happen to fail, leaven may be made in a ſhort time with rye-meal only wrought up into a ſomewhat thin dough with warm water, and kept in a gentle heat, till it has properly riſen*.

* Bread is the produce of the acetous fermentation, checked by baking or exſiccation, or in other words, by the ſubſtraction of its water: but no wine is produced here, becauſe neither ſugar nor water is preſent in ſufficient quantity. The effect of this incipient fermentation is to deſtroy part of the mucilage, or rather to divide and attenuate it: for, as we obſerved before, the mucoſity is by no means deſtroyed, nor even entirely ſeparated either in the firſt or laſt ſtage of this fermentation, part of it being nearly attenuated and held in ſolution in the liquor, as it is evident from the filaments produced in this latter during the proceſs, as well as from the ſediment depoſited at the bottom of the veſſel, and the thick and tough coriaceous ſubſtance that floats at top when the fermentation is finiſhed.

Hay is another inſtance of the acetous fermentation checked by exſiccation: and indeed an agreeable ſmell partaking of the vinous as well as acetous flavour is always perceived ſome time after the hay is laid up in ricks, when it undergoes the proceſs of *ſweating*, as it is called by the farmers, who, in many places ſuffer the fermentation to proceed to ſuch a pitch as, without great care and attention, would, by the violent heat it excites in ſo combuſtible and almoſt dry a ſubſtance, endanger the accenſion of the hay.

Another inſtance of this fermentation might have been mentioned by our author, viz. ſour krout, the preparation of which is ſo common in this country. Every one knows that this excellent antiſcorbutic is made by putting alternate layers of cabbage and ſalt in large tubs, where they are allowed to ferment together, and then kept cloſely covered from the air, generally by a coating of greaſe at top. But the produce of this proceſs, whether it be a true vinegar or a modification of that ſubſtance, has never yet, I believe, been enquired into.

With

With refpect to the third kind of fermentation, *putrefaction*, art has no concern in producing it; but on the contrary we muft endeavour, as much as poffible, to prevent and retard it; fince it is the common foe of all organized bodies. It manifefts itfelf firft in fuch bodies, as have already gone through the two former kinds, viz. the fpirituous and acetous fermentations, in the total deftruction, or rather evolution of the groffer compounds ftill remaining, and which already have held out the other two kinds. In this it chiefly affects the vifcid compound, and even the acid along with it, if this have not been previoufly feparated. But even though it have not been preceded by the other two fpecies, it may, notwithftanding, take place in a body, in confequence of the operations of certain occafional caufes, and produce in it this deftructive evolution*.

* Various have been, and ftill continue to be, the notions entertained both by philofophers and chemifts, with refpect to the extent as well as the nature of the procefs called Fermentation: fome confining it to the vinous and acetous proceffes, others including putrefaction, and others again extending it to every fpontaneous change that takes place in fluid and moift fubftances; fuch as germination and the maturation of fruits, chylification, various contagious diforders incident to the animal œconomy, as meafles, fmall-pox, &c.

But at prefent, till we are better acquainted with the hiftory of the different circumftances of this procefs, it would perhaps be adviseable to confine it to the ufual limits, comprehending the vinous, acetous and putrefactive fermentations.

Confidered in this light, *Fermentation* may be fimply defined; "The mutual action of the organic principle on water, and of water on the organic principle, by which, in a certain degree of heat, they decompofe each other."

It may be neceffary to obferve, that the principle here termed *organic* is, in the courfe of this work, conftantly denominated the *vegetable* principle, as it undoubtedly paffes from the vegetable kingdom into the bodies of animals, and conftitutes the chief part of their fubftance.

To all fermentation (as thus defined) are neceffary, 1. water; 2. more or lefs air; 3. a degree of heat, extending from about 32, or the freezing point of water, in Fahrenheit's thermometer, to fomewhat below 212, or the degree of heat at which water boils. Much below the former point, the water being folid, the organic principle will not be able to exert any action upon it: and near the latter point, the water will evaporate too faft for its decompofition to take place, in confequence of the action of the organic principle upon it; otherwife it is evident that, cæteris paribus, the nearer the fermenting body approaches to this point, the more rapid will be the progrefs of the fermentation.

It is likewife evident that no other bodies than thofe which have gone through the procefs of organization, are the fubjects of fermentation, which may be divided into two kinds: the *acetous* or acetification, and the *putrefactive*, or putrefaction. The former has been already defcribed; the latter may be defined thus:

It cannot be prevented better than by means oppoſite to thoſe by which it is promoted. Now it is well known that water, heat, and air, are the chief means of

*Putrefaction* is the mutual action of mucoſity, (unmixed with ſugar) upon water, or of water upon mucoſity, by which, in a heat, extending from 20 or 30 to 200 nearly of Fahrenheit, they decompoſe each other, and finally produce mould.

Putrefaction takes place ultimately in all organic bodies which have paſſed through the acetous fermentation: and likewiſe directly in all organic bodies, which, containing little or no ſugar, are not capable of that fermentation; and in proportion to the quality of ſugar they contain, the putrefaction of bodies is retarded in conſequence of its firſt going through the acetifying proceſs. The *ranceſcence* of fixed oils is an inſtance of the conjunction of both theſe proceſſes in one and the ſame ſubject.

Fermentation has been frequently defined to be an *inteſtine motion*; but the motion is frequently inſenſible, and therefore cannot enter into the nominal definition of their proceſs; and all action neceſſarily implying motion, in the real or genetical definition, the mention of this latter circumſtance is ſuperfluous.

A large maſs, mentioned by M. de *Fourcroy*, as one of the conditions, requiſite to fermentation, is by no means eſſentially neceſſary, either to the acetous or putrefactive proceſs; nor indeed, in all probability, to the firſt ſtage of the acetous; as in very ſmall quantities of a fermenting liquor, the ſpirit being produced gradually may be ſuppoſed to evaporate almoſt as ſoon as it is formed, or at leaſt too ſoon for any traces of it to be diſcovered in the liquor.

With reſpect likewiſe to the firſt condition, noticed by this philoſopher, as well as by our author, and moſt of thoſe who have lately written on the ſubject of fermentation, viz. a ſaccharine mucilage, it may be affirmed that no mucilage is neceſſary, except a mixture of ſugar and water be called by this name: all mucilaginous ſubſtances appearing capable of fermenting ſolely by virtue of, and in proportion to the quantity of the ſugar contained in them. If, indeed, the fermenting body contain mucilage, the texture of the mucilage will be partly broken down, as it were, and reſolved; and this is the chief uſe of fermentation in the making of bread: but it muſt be obſerved withal, that in the beſt bread, this is only done in part, as the bread ſtill remains adheſive and viſcid; and in fermenting liquors in general we ſee a great part of the mucilage depoſited among the lees at the bottom of the veſſel, not to mention what is born up to the top and works over the ſides of the caſk, in the form of yeaſt, nor what remains behind in the liquor of the fineſt and beſt fermented beers, in perfect union with the water and other conſtituent parts.

M. de *Fourcroy*'s ſecond condition, viz. "a degree of fluidity ſlightly viſcid," appears rather nugatory. "If the vegetable fluid be either too thick or too thin, it will not ferment," ſays this elegant writer, and, in general, acurate philoſopher. But what is this in fact, but ſaying, that there muſt be a certain proportion of ſugar and water? If there be too much of the former, ſo as to render the liquor too viſcid, the neceſſary motion will be impeded, and the caſe will be the ſame as in all other ſolutions in ſimilar circumſtances, (for fermentation may be aptly defined, "a continued ſolution, accompanied with continual compoſition and decompoſition;") all the particles of the menſtruum will not be able to come into contact with all the particles of the ſolvend. Beſides, the proportion of water being too ſmall, the event will be the ſame as when an

of promoting putrefaction. Our firſt endeavours conſequently are to be directed towards the *ſubſtraction of moiſture*, which in every kind of fermentation promotes the evolution of the parts. It is in conſequence of this that moſt vegetables and their different parts may be preſerved from corruption by mere exſiccation. It is very well known how much *cold* contributes to prevent

an acid, in a very diluted ſtate, is poured, on a metal on which it has otherwiſe no great action, no ſolution will take place. On the other hand, when the fluid to be fermented is too thin, the proportion of water is too great, and, in this caſe, the *ſpirituous* fermentation will not take place, or, if it do, the quantity of ſpirit produced will be imperceptible, and will fly off as faſt as it is generated. But then it cannot be truly ſaid, that the fluid will not ferment; for it will doubtleſs, accordingly as it contains more or leſs water, paſs over either to the acetous or putrid fermentation. Of the four conditions then aſſerted by M. de *Fourcroy* to be neceſſary to the ſpirituous fermentation, there is but one that is wholly incontrovertible, viz. the third, "of a degree of heat between fifty-five and ſixty-five of Fahrenheit."

As the decompoſition of ſugar is the direct and neceſſary conſequence of the acetous fermentation, ſo the immediate reſult of the putrefactive is the decompoſition of mucoſity, or mucilage and gluten; and accordingly as either mucilage or gluten is decompoſed, this ſpecies of fermentation takes the name of *vegetable* or *animal* putrefaction. But in both theſe kinds of putrefaction, the final reſult and intention of nature appears to be the generation of *mould*: in which ſtate of combination the vegetable (or organic) principle is beſt fitted to enter into and form the chief part of the ſubſtance of plants; and in conſequence of which only it returns (whether the mould be of vegetable or animal origin) to the ſtate and offices to which it was firſt deſtined.

This fermentation takes place immediately in all animal ſubſtances, and likewiſe in ſuch plants as, in their compoſition, make near approaches to the nature of animals, except theſe ſubſtances are combined with a conſiderable portion of ſugar, as for inſtance, in the urine of perſons afflicted with the diabetes, which firſt paſſes through the acetous fermentation; at leaſt the firſt ſtage, uſually called the vinous fermentation, has been frequently obſerved in this fluid. (But here it ſhould be remembered, that this is a morbid or preternatural ſtate; and perhaps does not naturally occur in any part of the animal ſyſtem.) In vegetables, on the other hand, excepting in the cruciform and ſome other plants, the putrefactive fermentation is conſtantly preceded by the acetous, which, however, does not deſtroy the mucilage of the ſubject, but, retaining a ſmall portion, ſeparates the greater part of it in the way of precipitation and coagulation. In this ſubſtance it is that the ultimate decompoſition of the vegetable takes place, and from which mould is finally produced. Unguinous oils, containing a certain quantity of mucilage, are ſuſceptible of the putrid fermentation, which the eſſential oil are not. But the former likewiſe appear to undergo the acid fermentation; and it is the mixture of the product of the two fermentations taking place almoſt at the ſame time, that forms what in theſe oils is called rancidity. [E]

putrefaction*. But where this is not fufficient, as is obferved to be the cafe with refpect to the prefervation of animal fubftances, they ought alfo to be deprived of the *accefs of air*. The air, it muft be owned, is frequently not hurtful in itfelf; but merely in confequence of the amazing number of infects contained in it, that darting down like the hawk upon a pigeon, with the greateft avidity upon the lifelefs animal parts, even after their exficcation promote the corruption of them. Thefe chiefly it is that by keeping off the air, muft, as unbidden guefts, be turned out of doors. With this view, care fhould be taken in collections of natural hiftory, that the fpecimens, where it is practicable, be well dried and kept in well-clofed cafes. The fame end too is obtained, particularly in fuch fubftances as cannot be dried at all without injuring their form, by pouring fpirit of wine upon them; which in the firft place ferves fuch bodies for a covering; in the next place it penetrates them and deprives them by degrees of their aqueous parts; and laftly, hardens them by conftringing their flefhy fibres. It is attended indeed with this inconvenience, that the fpirit of wine in the beginning frequently becomes weak and watery, and requires to be decanted off, and ftrengthened by the addition of frefh fpirit. Finally, the continual evaporation of the fpirit of wine, how well foever the glaffes are clofed, is not eafily avoided. Befides this, there are ftill other means to preferve animal fubftances; which confift in expofing them to be penetrated by fuch particles as prevent putrefaction in two different ways, and are on the one hand, of a faline, and on the other, of an oily inflammable nature. To the former may be referred thofe inftances in which corruptible fluids are beft preferved by means of mineral acids; as alfo the *falting* and *fmoking* of meat, in which latter cafe the privation of moifture and the penetration of the oily acid of the wood are the principal agents. Under the fecond may be ranked the *embalming* of corpfes, the chief point of which confifts in the extraction of all the foft and fluid internal parts, and on the penetration of the flefhy parts by refinous fubftances rendered liquid with fpirit of wine. The *Bilfian* method of embalming is an inftance of a profufenefs of this kind. The fame thing takes place in the injection of the veffels of the human body with wax for anatomical preparations.

* For the method of keeping meat frefh in olive oil, Vid. Journ. de Phyfique, Tome II, Part I, page 75—84.

CHAP.

# CHAP VI.

## PHLOGURGY, or the CHEMISTRY of Inflammable Bodies.

BY *Inflammable Bodies* are underſtood ſuch as are endued by nature with the property of taking fire and of burſting out into flame, by which they are evidently diſtinguiſhed from all other bodies. Hence it is natural to conceive that they muſt contain a great quantity of the matter of fire in their compoſition, whether this be contained in them directly in their primitive pure ſtate, or in their phlogiſtic compoſition. This matter is always the chief efficient cauſe of one body being ſet on fire by another that is already in a ſtate of ignition, as by this means the confined matter of fire is excited to break forth. An eruption of this kind, according to the nature of the other ſubſtances with which the igneous matter is united, is manifeſted either by ſimple ignition or by flame. As in general ſaline particles are diſcoverable in the compoſition of theſe bodies, it is ſuppoſed that they have the power of fixing the igneous particles. The inflammation of a body conſequently is the viſible eruption of theſe igneous particles in union with other volatile particles that eſcape at the ſame time with them. For the reception of theſe, the free acceſs of air is requiſite; hence no fire can burn without air, and any fire in a cloſe room laſts only in proportion to the capacity of that room, or to the quantity of air which is preſent; without which, the particles of an inflammable body, when forced to ſeparate by any external fire, are merely ſeparated from each other without being deſtroyed*. We meet with theſe ſubſtances in all the three kingdoms

* Mere heat, whether preceding ab extra, or produced in the body itſelf, acts no otherwiſe on a body (excepting in the caſe when ſome of the heterogeneous or conſtituent parts of the body are more volatile than the reſt) than by ſetting the integrant or homogeneous particles of it at a diſtance from each other: but if air be preſent and the body contain phlogiſton, i. e. fire in a fixed

kingdoms of nature, which however, in the reft of their compofition differ much from each other. They may confequently be difcriminated into two principal kinds, viz. into fuch as mix with water, and fuch as will not unite with it.

The former of thefe, which are *foluble in water*, may be divided again into *dry* and *liquid* fubftances. To the *dry* may be referred the combuftible falts, which on account of their faline properties predominating, have already been treated of in the chapter upon Halurgy. Of the liquid kind, *Spirit of Wine* is only known. By this is underftood, a very volatile fluid which is eafily fet on fire, which in burning yields no foot at all, but is confumed entirely, and which mixes eafily with water. Its origin has been defcribed in the Zymotechny.

I maintain that there is but one fuch inflammable fpirit exifting in nature, though it may be obtained from different bodies. The only difference perceivable in fuch cafes, proceeds merely from certain ethereal or volatile acid parts which are ftill combined with it; when purified from thefe, there does not fubfift any particular difference between the various fpecies of ardent fpirits, and leaft of all in their chief properties. This fpirit, whether extracted from wine or any other body whatever, is ufually called *Spirit of Wine*, becaufe it was formerly extracted from wine only. But in our times we prefer drinking the wine, and extract the fpirit from other vegetable fubftances. The time of its difcovery is not exactly known; but there is reafon to fuppofe that it was not noticed before the tenth century. Since that time it was mentioned by a Florentine called *Thaddæus*, who died in 1270, at the age of eighty years.

When the ardent fpirit is fo far freed from accidental impurities and the fuperfluous quantity of water with which it is mixed in the firft diftillation, when it conftitutes the *common brandy* or *melaffes fpirits* of commerce, it contains half water, rather lefs than more, of which it muft be deprived by feveral more diftillations. This is effected by diftilling common brandy again by itfelf in the fame ftill, with a moderate fire, till an aqueous fluid begins to come over. But it is better

fixed ftate, the particles of the body being by the interpofition of heat in its elaftic ftate removed to a greater diftance from each other than they were before, in confequence of which, their mutual attraction is diminifhed, the air is enabled to unite with fome of the conftituent parts, by which means others are difengaged, and amongft the reft, light, which in its fixed ftate being always combined with a large portion of heat, now parts with it, and both thefe fluids being evolved, the body burfts forth into a *flame*, and is *confumed* and *burned*; i. e. it has parted with its phlogifton and entered into new combinations. [E]

to put into the ſtill, at the ſame time, a little lime, clean ſifted aſhes or fixed alkali, by which the abovementioned volatile acid, and other ethereal parts are retained and remain behind in the ſtill with the reſt of the phlegm. The ſpirit that is obtained in this manner, is now much purer and ſtronger, and is called *Rectified Spirit of Wine* (Spiritus Vini Rectificatus). But even this ſpirit is not entirely deprived of its phlegm, but generally ſtill contains one eighth of water. To be deprived of this, it muſt be diſtilled once more in a clean ſtill, by a gentle heat, either entirely by itſelf, or with the abovementioned additions, ſo long as it is obſerved to be watery, or in the leaſt weak. It then bears the name of *Alcohol*, or *highly rectified Spirits of Wine* (Spiritus Vini rectificatiſſimus). Spirit of wine may alſo be deprived of its water without diſtillation, by adding to every pound of it two ounces of perfectly dry and good pot-aſh, and keeping it in a glaſs cloſe ſtopped for ſome days. The pot-aſh, in conſequence of the ſtronger affinity it bears to water, quits the ſpirit, unites with the fixed alkali, and ſinks with it to the bottom of the veſſel, ſo that the ſpirit may be decanted from it. In this ſtate it is called *Tartarized Spirit of Wine*. It muſt be obſerved, however, that in this operation, the ſpirit of wine diſſolves a little of the alkali, whence it cannot be employed generally on all occaſions, unleſs indeed it be diſtilled over once more.

The ſtrength of the ardent ſpirit, or the quantity of water contained in it, may be aſcertained in two different ways, viz. by ſetting it on fire, and by the difference of its ſpecific gravity. With the former view, a ſmall ſhallow china ſaucer or glaſs is to be accurately weighed, and half an ounce or an ounce of ardent ſpirit poured into it, the ſaucer put into water, and the ſpirit ſet on fire. As ſoon as it is conſumed, the ſaucer is taken out of the water, wiped dry on the outſide, put into a pair of ſcales, and thus it is diſcovered how much water is left in it. When the ſaucer is not put into water, it is heated to ſuch a degree during the combuſtion of the ſpirit, that a conſiderable portion of the remaining water evaporates, and the proof turns out falſe. This trial is ſureſt when made with rectified ſpirit. The trial, whether alcohol be abſolutely free from water, is made by wetting ſome gun-powder, cotton or flax, with it, and then ſetting it on fire; if at the end they burn and are conſumed along with it, this is a ſign of its goodneſs. Another method of judging of the ſtrength of this fluid, is by means of the areometer, with the ſcale of which, however, the operator ought to be previouſly acquainted. The deeper this inſtrument ſinks in the water, the better is the ſpirit. This inſtrument is particularly uſeful in the purchaſe of common ſpirits or brandy.

With respect to the constituent parts of wine, it is proved, by the latest experiments made by M. *Westrumb*, that water, acid of tartar *, and phlogiston, may be procured from it. Spirit of wine appears to be acid of tartar dulcified by phlogiston and water. The saccharine acid which has been obtained from spirit of wine by the assistance of nitrous acid, comes from the dephlogistication of the acid of tartar, and ought therefore to be considered as a remote constituent part; as also the acetous acid, which is the basis of these two acids, and which, by a farther dephlogistication of the saccharine acid may be produced from it; it may properly be considered as the most remote of the acid component parts of spirit of wine †.

* It does not appear that there is an acid of any kind in pure ardent spirit, or spiritus vini tartarizatus; as, what existed in it after the first distillation must certainly have been entirely neutralized by the tartar. In wine, it is true, there is always more or less of an acid; but this, in distillation, is left behind. Alcohol, or pure ardent spirit, seems rather to be composed of a subtle oil, united with inflammable gas, the vegetable principle and water. As there is an oil in sugar (of which wine and therefore spirit of wine is made) it is reasonable to suppose that it still exists either virtually or actually, in this latter fluid. [E]

† Vid. *Westrumb's* Chemical Experiments relative to the Saccharine acid, its nature, and the constituent parts of spirit of wine, in his Kleine phys. Chem. Abhand. Leipsick, 1785. Part I. [A]

M. *Hermbstadt* has since shewn that the vegetable acid passes through another modification, viz. that of the *Melic* acid, before it is entirely simplified. The gradations appear to be as follows: The *Tartaric*, the *Apple*, (or *Melic*), the *Saccharine*, (or rather *Oxaline*), the *Acetous*, and lastly, the *Aerial acid*. These are all formed of the vegetable principle united with a quantity of air, increasing according to the order in which they are here placed. It is commonly supposed by the adherents to the ancient doctrines, that these changes are made merely by depriving the preceding acid of the phlogiston still contained in it. The favourers of the new theory, on the contrary, attribute these effects to the addition of pure air. Both these conditions certainly take place: but there seems to be another that has not been sufficiently attended to by either party: this is, the privation of the oil of the vegetable, which adheres in different quantities to all these acids. This is gradually destroyed in each operation, as is evident by the quantities of inflammable gas producible from them, till in the aerial acid it is entirely wanting. The enormous quantity of inflammable gas produced in the distillation of tartar, has been noticed by *Hales*, van *Helmont*, and the most ancient of chemists: and among others, Dr. *Higgins's* experiments lately published, evidently shew that there still remains a portion of this gas, and consequently of oil, in the purest distilled vinegar: whereas by no experiments as yet has the presence of it in the aerial acid been manifested, although it be pretty generally allowed (and, indeed, there are facts that prove it) that this acid still contains phlogiston. Indeed it is highly probable that there is no more phlogiston in one of these acids than in the other, excepting that portion which exists in the oil, with which all, but the aerial, are united. [E]

There is no ſure and unequivocal criterion by which genuine ſpirit of wine can be diſtinguiſhed from purified ardent ſpirit, extracted from any other vegetable matters; this may be conſidered as a proof of its univerſality. It has been eſteemed by ſome as a ſign that French brandy is genuine, when upon being mixed with ſome drops of a ſolution of martial vitriol, it acquires a blue colour; but this mark is not to be depended on. French brandy has its yellowiſh colour from the caſks in which it is kept, and every ſpirit extracted from corn may acquire this colour in the ſame manner, and then they will both exhibit the ſame property. The ſmell and taſte after all are the moſt certain criterions by which we can decide. It may however be ſo managed by art, that theſe ſenſes ſhall not be able to determine between them. When rectified malt ſpirit has been diſtilled from a proper proportion of colcothar, it will acquire a ſmell and taſte ſimilar to thoſe of French brandy. I have lately diſcovered a ſimilar effect in the fluor acid, from which common ſpirit of wine acquired the moſt perfect ſmell of arrack.

Spirit of wine is the moſt perfect ſolvent of etherial oils, camphire, reſins, ſoaps*, and different ſalts. In the ſolution of etherial oils it is obſerved in general, that ſome are more eaſily diſſolved and in greater quantity than others. The caſe is the ſame with reſpect to reſins. Some gummy reſins alſo combine with it. It particularly diſſolves fixed cauſtic alkaline ſalts, terra foliata tartari, volatile alkali, ſedative ſalt, ſalt of benzoe, ſalt of amber, corroſive ſublimate, ſugar of lead, &c. ſome of which alſo alter the colour of its flame. From the ſolution of cauſtic alkali in alcohol the *tincture of ſalt of tartar* is made, by adding to every pound of alcohol two ounces of cauſtic alkali †. The

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* The late Dr. *Elliot* has obſerved that the ſame bodies exert different elective attractions upon each other, accordingly as they are diſſolved either in water or in vinous ſpirit. Thus, if expreſſed oil be mixed with ſlaked lime into a paſte, ſo as to form a calcareous ſoap, and mild alkali be added; the latter will not decompoſe the former either in water or by fuſion. But if ſpirit of wine be ſubſtituted for water, an alkaline ſoap and mild calcareous earth will be formed.

Again, if mild fixed alkali be added to Diachylon plaiſter, in hot water, they unite together in a gelatinous maſs, which is miſcible with the water. This may be conſidered as a kind of hepar: and from it, by a ſpirit of wine, may be extracted a ſoap, which however contains a ſuperfluous quantity of oil. The ſame phenomena take place on the addition of chalk.—Likewiſe ſea-ſalt and nitre are decompoſed by Diachylon plaiſter, in hot ſpirits of wine: which does not happen either in water or in the dry way. Vid. *Elliot*, Phil. Tranſ. Vol. LXXVI, pag. 155. [E]

† On this occaſion M. *de Fourcroy*, Vol. IV, pag. 155, juſtly obſerves, fixed alkalies appear actually to decompoſe ſpirit of wine. This tincture, on diſtillation, affords ſpirit of wine ſcarcely



altered

red colour which the ſpirit of wine acquires in this operation, is derived from the ſtrong action of the matter of fire upon the ethereo-oleaginous parts of the ſpirit; on which account this liquid in like manner acquires a dark colour from the admixture of concentrated ſmoaking oil of vitriol. It commonly acts but very little upon mineral oils; but when a drachm of oil of vitriol is previouſly mixed with an ounce of alcohol, the ſolution of oil of amber is eaſily accompliſhed. There is the ſame difficulty likewiſe with reſpect to the bitumens, from which it otherwiſe extracts a ſmall portion of a reſinous ſubſtance a little altered. I have not been able as yet to diſſolve amber perfectly; though the poſſibility of it has lately been affirmed for a certainty, of which indeed I do not doubt, on account of ſome ſimilar phenomena that have occured to myſelf. From the ſolvent power of this fluid reſult all the tinctures and eſſences which are prepared with it, whoſe component parts again, when extracted, muſt be judged of by this ſame property. Likewiſe, as ſpirit of wine carries over along with it in diſtillation all the ethereal oils from bodies, and at the ſame time diſſolves them, various ſubſtances containing theſe oils are added to it previous to the diſtillation, and the ſpirit is diſtilled from them, in which manner a great variety is prepared in the ſhops, of oily odorous ſpirits, and ſpirituous waters, which are then named after the ſubſtances they are extracted from, or elſe from their effects. It is moreover remarkable, that thoſe bodies which have been diſſolved by ſpirit of wine, when water is not likewiſe capable of diſſolving them, are ſeparated by this latter fluid; on the other hand, alcohol has in various caſes the power of ſeparating many of them from their combination with water.

Divers volatile acids, when mixed in ſmall quantities with ſpirit of wine, and united with it more intimately by diſtillation, are, as it were, abſorbed by the ſpirit of wine, and by this means their acrimony is obtunded, ſo that their acid part becomes more or leſs imperceptible. Hence theſe and ſimilar preparations

altered, and a ſubſtance remains in the retort reſembling a ſaponaceous extract, which, diſtilled with a naked fire, yields ſpirit of wine, volatile alkaline ſpirit, and a light empyreumatic oil. In this operation, a ſmall quantity of charcoal is formed, which is found to contain the vegetable alkali. The experiment ſeems to ſhew, that ardent ſpirit contains an oil that is ſeized by the fixed alkali, and forms a true ſoap held in ſolution in the portion of ſpirit which is not decompoſed. The tincture of antimony (page 311), and Lilly of Paracelſus (page 313), do not differ from this, excepting that in theſe the fixed alkali appears to be rendered ſtill more cauſtic by the metallic calces with which it was heated. [E]

bear

bear the name of *dulcified acid ſpirit* (ſpiritus acidi dulcificatus). By this appellation are underſtood ſweet-ſcented, ſulphureous and inflammable ſpirits *; the change produced in which proceeds from the operation of the acid combined with them. Of all acids, thoſe of vitriol, nitre, ſea-ſalt, vinegar, wood, tartar, urine, fat and ants, are fitteſt for this purpoſe. For producing them, the following rules are in all caſes to be obſerved: 1. That both the ardent ſpirit and the acid be deprived of water as much as poſſible: 2. that the liquors, after being mixed together, be kept for ſeveral days in a cool place: 3. that the diſtillation be carried on with the moſt gentle fire: and 4. that it be finiſhed at the proper time.

The *dulcified Spirit of vitriol* † (Spiritus Vitrioli dulcis), is at preſent known by the name of *Hoffman's anodyne liquor* (liquor anodynus mineralis *Hoffmanni*), and is prepared in the following manner. From four to ſix pounds of the ſtrongeſt alcohol are poured into a large phial with a narrow mouth, and then one pound of the ſtrongeſt oil of vitriol is gradually added to it, a little at a time. As ſoon as the phial is perceived to grow warm, the addition of more oil of vitriol is put a ſtop to for ſome time, and the glaſs ſtopped up, and ſuffered to ſtand undiſturbed till it is grown cold again. Small portions of oil of vitriol are then added again, till the glaſs grows warm, which is then ſet by once more to cool, and the proceſs is thus continued, till the whole of the oil of vitriol is poured in. The mixture now remains ſtanding in the phial with the cork tied down faſt, for four, ſix, or eight days, after which it is poured into a retort, which is ſet in a ſand-heat, and furniſhed with a receiver, that fits it well, and is luted to it very carefully. The next day the diſtillation is made by a ſlow fire, and conducted in ſuch a manner, that the receiver never becomes warm. The diſtillation will either require one or two days, according to the quantity of the ingredients. In fact, it is continued till ſomewhat of a ſulphureous ſmell is perceived at the juncture of the veſſels. As ſoon as this odour is perceived, the ſpirit that is come over muſt be removed, that it it may not be contaminated by this ſulphureous matter. As

* Why ſulphureous? This epithet ſurely can at beſt accord only with the dulcified ſpirit of vitriol. As conſiſting of an acid (or rather the baſis of an acid) and phlogiſton, they may indeed be called ſulphureous: but then alcohol, and in general all ſubſtances containing combinations of acids with the inflammable principle, muſt bear the ſame denomination, which in this caſe would be too general. [E]

† A mixture of this kind, ſet apart without being diſtilled, bears the name of *Rabel's Water*. (Eau de Rabel). [A]

every thing depends on the due obſervation of this critical inſtant, it is adviſeable before this arrives, to empty the receiver frequently, till at length, by repeated practice, we have acquired a ſufficient and certain judgment. Towards the end of the operation, together with a ſmall portion of a ſomewhat acidulous phlegm, there paſſes over a ſubtle ſweet-ſcented oil, which however muſt not be ſeparated here, if it be meant that the liquor ſhall poſſeſs the qualities generally required in it; but the acidulous phlegm upon which the latter product ſwims may be ſeparated, and the oil poured on to the ſpirit that came over firſt. The reſiduum in the retort may be mixed with freſh alcohol ſeveral times more, with the ſame effect, and treated in the ſame manner as before. When by any neglect the ſpirit is contaminated with a little acid, or with a ſulphureous ſmell, it muſt be rectified afreſh over a few ounces of dry alkali.

The preparation of *dulcified Spirit of Nitre* (Spiritus Nitri dulcis) is the ſame in the main with the preceding; it is prepared with alcohol and nitrous acid. For this preparation, the nitrous acid may be employed either in its ſtrongeſt ſmoking ſtate, or elſe at all events, in a ſomewhat more diluted ſtate. In the former caſe, from ten to twelve parts of alcohol muſt be taken to one of acid; in the other, from five to ſix parts. In applying the ſmoking acid, it ſhould be added to the alcohol with yet greater caution, and in ſtill ſmaller portions than the vitriolic acid, becauſe in this, the effects proceeding from its elaſticity are more conſiderable. After the mixture is made, the glaſs is in like manner ſuffered to ſtand, well ſecured, for ſeveral days, and then the mixture is diſtilled in a retort, with a gentle heat, till ſome phlegm begins to come over. When by the taſte, or other criterions, we are led to ſuſpect that the ſpirit contains ſome uncombined acid, a proportionable quantity of alcohol being mixed with it, it may be rectified afreſh; or a little alkali is added to it without alcohol, and the ſpirit abſtracted by a gentle heat. This ſpirit is mentioned by *Raymond Lully* and *Baſil Valentine*.

*Dulcified Spirit of Salt* (Spiritus Salis dulcis) is beſt prepared according to *Weſtrumb's* method, by mixing of common ſalt four ounces, of oil of vitriol and manganeſe, of each two ounces, with from eight to twelve ounces of alcohol, and diſtilling the mixture to dryneſs in a retort. Without the intervention of manganeſe, marine acid alone does enter into a cloſe union with the vinous ſpirit*.

* Vid. Chem. Journ. Vol. IV. pag. 11—42. Neueſte Entdeck, in der Chemie, Vol. IV. pag. 58. Vol. V. pag. 84—90. Vol. VI. pag. 101—8. Vol. VII. pag. 17—19, 89. Vol. VIII, pag. 82—96. [A]

For the preparation of *dulcified Spirit of Vinegar* (Liquor anodynus Vegetabilis) in *Weſtrumb*'s method, three or four parts of alcohol may be mixed and diſtilled with one of concentrated acetous acid, (vid. page 181). In a ſimilar manner, a *dulcified Vinegar of Wood* may alſo be obtained, by mixing one of concentrated lignic acid, or the ſpirit which comes over laſt in the rectification of vinegar of wood, with the ſame quantity, or two parts of alcohol, and diſtilling this mixture ſecundum artem. Of a *dulcified acid of Tartar* we have a very remarkable inſtance in the *mixtura ſimplex*, which is obtained by diſtilling together five parts of ſpiritus theriacalis, three of ſpirit of tartar, and one of ſpirit of vitriol; the formula and title of which comes from *Theophraſtus Paracelſus*. In ſimilar circumſtances, according to *Weſtrumb's* recipe, from the acid which is expelled from the ſalt of urine by oil of vitriol, in the proportion frequently mentioned, and from alcohol, may be obtained a *dulcified Acid of Urine* (Liquor anodynus Animalis). In the ſame manner the *ſebaceous acid* may be dulcified with alcohol, and a peculiar ſpirit obtained. Among theſe too, may in ſome meaſure be ranked the officinal *Spirit of Ants*. In all theſe, and ſimilar dulcified acids, the acid is ſo enveloped and confined by the phlogiſtic part of the ſpirit of wine, as no longer to occaſion any effervefcence with alkaline ſalts. Taken in this light, they muſt be conſidered as ſulphureous compounds; in fact, their peculiarly ſtrong and volatile ſmell proceeds from the combination of the acid with the oily part of the ſpirit of wine; and, indeed, is modified in a different manner in each acid, accordingly as it differs from the reſt. In this very circumſtance too, a certain reſemblance is diſcoverable in them, to the combuſtible ſalts and the volatile ſpirit of ſulphur.

The *combuſtible ſubſtances inſoluble in Water*, which form the ſecond Claſs, are by this very circumſtance differently diſtinguiſhed from the preceding; excepting, indeed, that in many inſtances, they contain real ſaline particles. They may be ſub-divided into *oily*, *reſinous* and *ſulphureous*.

By *oily ſubſtances* are underſtood both *oils* themſelves which are inflammable fluids, not ſoluble in water, and hence cannot be intimately mixed with them, and alſo ſuch bodies as have theſe oils for their baſes, but which by certain additions have been inſpiſſated and brought into a concrete ſtate. Conſequently, oleaginous bodies in general may be divided into *fluid* and *ſolid*; and more particularly into *ethereal*, *unguinous* and *empyreumatic* *.

Ethereal

* The diviſion of oils into *fixed* and *volatile*, adopted by the celebrated authors of the *Nomenclature*,

Ethereal oily fubftances are fuch, as have a volatile fpirituous fmell, are more or lefs foluble in fpirit of wine, but do not enter into a clofe union with water, According to their external appearance they are either *oils*, *balfams*, or *refins*.

*Ethereal* oils bear this name, on account of their volatile, and as it were, aerial nature. They are fometimes alfo called *diftilled* oils, from the circumftance of their being obtained by diftillation. The former name relates to the nature, the latter to the manner in which they are produced; of the two, the former is more determinate and more fuitable to their nature. Some chemifts alfo have termed them *effential* oils; but this appellation is too vague, as the expreffed, empyreumatic and mineral oils have an equal claim to this title.

Thefe oils are chiefly contained in different vegetables and their parts, in which their prefence is readily difcoverable by a ftrongly volatile and balfamic fmell. From thefe they are feparable by pouring a fufficient quantity of water upon thefe bodies, and diftilling it from them, till there is fcarcely any veftige of oil to be perceived upon the water that comes over. It will then be found that the oils thus obtained contain all the fmell, and fometimes alfo the tafte of the body, from which they have been extracted; in confequence of which alfo the refiduum has loft thefe fenfible qualities. There are indeed feveral vegetables that have an an agreeable flavour, and notwithftanding yield no ethereal oil on being diftilled with water, of which lilies, hyacinths, clove-July flowers, violets, the bloom of the lime or linden-tree, lilies of the valley, &c. are ufually adduced as inftances; a fact which might be oppofed to what I have afferted juft above. But this objection is eafily overturned, as I think I can prove that the reafon why none of thefe fubftances yielding etherial oil, is only becaufe they contain but a fmall, though a ftrong-fcented portion of this oil, which is imbibed by the water employed in the diftillation, whence this alfo acquires the fame fmell, as was originally poffeffed by the vegetable itfelf. All thefe bodies yield no oil, only as long as they are not fubmitted to diftillation in a certain quantity, which is generally very confiderable. Formerly rofes, orange-flowers, and feveral other fimilar fubftances, which contain but very little oil, were likewife ranked among thefe, as they alfo yield no oil, when they are in a fmall quantity; but it is now known for a certainty, that in large quantities neverthelefs, thefe fubftances afford

*clature*, is much more philofophical and accurate: the former comprehending what are commonly called *unguinous* oils, the latter the *ethereal* and *empyreumatic*. [E]

a ſmall portion of oil. We experience it ourſelves, that vegetables, which are certainly known to contain etherial oil, when diſtilled in ſmall quantities, yield an odorous diſtilled water only, in which frequently not the leaſt veſtige of ſuch oil is diſcoverable. I cannot therefore help ſuppoſing that if thoſe vegetables, which produce an odorous water, were ſubmitted to diſtillation by the hundred weight, they would yield an ethereal oil juſt as well as the others; when we ſhould neceſſarily be convinced, that the whole of their ſmell is derived from a ſmall quantity of a ſtrong-ſcented ethereal oil.

Theſe oils however are not always contained in every part of a plant. They ſometimes reſide merely in the herb or in the leaves, ſometimes in the roots, flowers, ſeeds, fruits, wood, bark, ſeed-veſſels, or chives, or in the balſamic or reſinous part. Their preſence in theſe parts are diſcoverable by the ſmell. In theſe they are commonly in appropriated veſſels, which however are ſometimes ſo ſmall that they cannot be diſtinguiſhed by the naked eye, yet in ſome they may be obſerved by the aſſiſtance of microſcopes, as for inſtance, in nutmeg, angelica and maſter-wort, juniper-berries, lemon and orange-peel. From theſe two laſt, the Italians are accuſtomed to ſeparate the oil by expreſſion, by which means they preſerve their natural agreeable odour and taſte.

With reſpect to quantity, theſe oils are alſo found in very different proportions in the ſubſtances which contain them. Some yield them only in very ſmall, ſome in middling, and ſome in greater quantities. It is true, I do not ſuppoſe it poſſible accurately to determine the quanty of oil yielded by each ſubſtance; it is however a very deſirable thing even to know nearly the proportions of them. In this view, conſequently, the following table may be of uſe; which at leaſt will furniſh a great deal of information to ſuch as may wiſh to proſecute the ſubject.

TABLE

TABLE, exhibiting the Quantity of ETHEREAL OIL obtained from different VEGETABLES.

| Name of the Vegetable. | Quantity. | Weight of the oil. | Maker of the experiment. |
|---|---|---|---|
| AGALLOCHUM wood | 10 lb. | 4 drachms | Hoffmann |
| Angelica root | 1 lb. | 1 drachm | Cartheuſer |
| Aniſeed | 1 lb. | 2 drachms | Neumann |
| Aſſafœtida | 4 ounces | 1 drachm | Neumann |
| Balm, common | 6 baſkets | 1 drachm | Dehne |
| —— Turkey | 6 baſkets | 2 ounces | |
| Cajaput ſeeds | 1 lb. | 15 grains | Dehne |
| Calamus aromaticus | 50 lb. | 2 ounces | Hoffmann |
| —— —— | 1 lb. | 2 ſcruples | Neumann |
| Camomile flowers, common | 1 lb. | ½ drachm | Cartheuſer |
| —— —— —— | 6 lb. | 5 drachms | Lewis |
| —— —— —— | 200 baſkets | 1 lb. | Dehne |
| —— —— wild | 1 lb. | 20 grains | Cartheuſer |
| —— —— —— | 6 lb. | 2½ drachms | Lewis |
| —— —— Roman | 30 lb. | 1¾ ounces | Dehne |
| Caraway ſeeds | 4 lb. | 2 ounces | |
| —— —— | 2 lb. | 9 drachms | Lewis |
| —— —— | 1 cwt. | 83 ounces | |
| Cardomum ſeeds | 1 ounce | 1 ſcruple | Neumann |
| Cariophilli Plinii | ½ lb. | ½ ounce | Dehne |
| Carline thiſtle root | 1 lb. | 2½ ſcruples | Neumann |
| Carrot ſeeds | 2 lb. | 1½ drachm | Lewis |
| Caſcarilla bark | 1 lb. | 1 drachm | Cartheuſer |
| —— —— | 30 lb. | 4 ounces | Dehne |
| Caſſiæ flores | 1 lb. | ½ drachm | Cartheuſer |
| —— —— | 30 lb. | 4 ounces | Dehne |
| Cedar wood | 1 lb. | 2 drachms | Marggraf |
| Chervil leaves | 9 lb. | ½ drachm | Neumann |
| Cinnamon | 1 lb. | 1 drachm | Sala |
| —— | 1 lb. | 2½ ſcruples | Neumann |
| —— | 4 lb. | 6 drachms | Lemeri |

| Name of the vegetable. | Quantity. | Weight of the oil. | Maker of the experiment. |
|---|---|---|---|
| Cinnamon | 1 lb. | 2 drachms | Cartheuser |
| —— | 1 lb. | 8 scruples | Cartheuser |
| —— | 3 lb. | 4 drachms | Dehne |
| Clary (garden) the seeds | 4 lb. | 2 drachms | Lewis |
| —— in flower, fresh | 130 lb. | $3\frac{1}{2}$ ounces | |
| Cloves | 1 lb. | $1\frac{1}{2}$ ounce | Teichmeyer |
| —— | 1 lb. | $2\frac{1}{2}$ ounces | Cartheuser |
| —— | 2 lb. | 5 ounces | Hoffmann |
| —— | 2 lb. | 5 ounces | Dehne |
| —— | 1 lb. | 1 oz. 6 drach. | |
| —— | 1 lb. | $2\frac{1}{2}$ ounces | |
| —— | 1 lb. | 2 oz. 2 drach. | |
| Copaiba balsam | 1 lb. | 6 ounces | Hoffman |
| —— —— | 1 lb. | 8 ounces | Lewis |
| Culilabani cortex | 1 lb. | 1 drachm | Vogel |
| Cummin seed | 1 lb. | 5 drachms | Vogel |
| —— —— | 1 bushel | 21 ounces | Lewis |
| Dill seed | 4 lb. | 2 ounces | Lewis |
| —— with the tops | 6 baskets | 8 ounces | Dehne |
| Dittany of Crete | 1 lb. | 30 grains | Lewis |
| Elecampane root | 2 lb. | $3\frac{1}{2}$ scruples | Neumann |
| ——, dry | 12 lb. | $3\frac{1}{2}$ drachms | Dehne |
| Elemi (gum) | 1 lb. | 1 ounce | Neumann |
| Fennel seed (common) | 1 lb. | 8 scruples | Neumann |
| —— sweet | 1 bushel | 18 ounces | Lewis |
| Feverfew flowers | 1 basket | 2 drachms | Dehne |
| Galangal root | 1 lb. | 1 drachm | Cartheuser |
| Garlic root, fresh | 2 lb. | 30 grains | Neumann |
| Ginger | 1 lb. | 1 drachm | Neumann |
| Horse-radish root | 1 lb. | 15 grains | Vogel |
| —— —— | 8 ounces | 15 grains | Neumann |
| Hyssop leaves | 2 lb. | $1\frac{1}{2}$ drachm | Neumann |
| —— —— | 1 lb. | $1\frac{1}{2}$ drachm | Cartheuser |
| —— —— | 1 lb. | 2 drachms | Cartheuser |
| —— —— | 2 cwt. | 6 ounces | Lewis |
| —— —— | 10 lb. | 3 drachms | |
| —— —— | 30 lb. | 9 drachms | |
| Juniper berries | 8 lb. | 3 ounces | Hoffmann |
| —— —— | 1 lb. | 3 drachms | Cartheuser |
| —— —— | 48 lb. | 6 ounces | Dehne |
| —— —— | 60 lb. | $6\frac{3}{4}$ ounces | |
| —— wood | 15 lb | 2 ounces | |

| Name of the vegetable. | Quantity. | Weight of the oil. | Maker of the experiment. |
|---|---|---|---|
| Lavender in flower, freſh | 48 lb. | 12 ounces | Lewis |
| ——— ——— | 30 lb. | 6¾ ounces | |
| ——— ——— | 13½ cwt. | 60 ounces | |
| ——— ——— | 2 lb. | 4 drachms | Hoffmann |
| ——— ——— dry | 4 lb. | 2 ounces | Lewis |
| ——— ——— | 2 lb. | 1 ounce | Hoffmann |
| ——— ——— | 4 lb. | 3 ounces | |
| ——— broad-leaved, dry | 4 lb. | 1 ounce | |
| ——— ——— ——— | 1 lb | 1 drachm | Cartheuſer |
| Lovage root | 1 lb. | 1 drachm | Cartheuſer |
| Mace | 1 lb. | 5 drachms | Neumann |
| Marjoram in flower, freſh | 85 lb. | 3¾ ounces | Lewis |
| ——— ——— ——— | 13½ lb. | 3½ drachms | |
| ——— ——— ——— | 34 lb. | 1½ ounces | |
| ——— leaves, freſh | 18½ lb. | ½ ounce | |
| ——— ——— dry | 4 lb. | 1 ounce | Hoffmann |
| Maſterwort root | 1 lb. | ½ drachm | Neumann |
| Milfoil flowers | 18 baſkets | 4½ ounces | Dehne |
| ——— dry | 14 lb. | 4 drachms | Lewis |
| Mint in flower, freſh | 6 lb. | 4½ drachm | Lewis |
| ——— leaves, dried | 4 lb. | 1½ ounce | Hoffmann |
| ——— ——— freſh | 30 baſkets | 1¼ lb. | Dehne |
| Mother of thyme | 45 lb. | 4 drachms | Dehne |
| Myrrh | 1 lb. | 2 drachms | Hoffmann |
| | 1 lb. | 3 drachms | Neumann |
| Nutmegs | 1 lb. | 1 ounce | Hoffmann |
| ——— | 1 lb. | 1 ounce | Geoffroy |
| ——— | 1 lb. | ½ ounce | Neumann |
| ——— | 1 lb. | ¾ ounce | Sala |
| ——— | 1 lb. | 5 drachms | Cartheuſer |
| Parſley ſeeds | 2 lb. | 1 drachm | Lewis |
| ——— leaves, freſh | 238 lb. | 2 ounces | Lewis |
| ——— leaves with the ſeeds | 15 baſkets | 14½ ounces | Dehne |
| Parſnep ſeeds | 8 lb. | 2 drachms | Lewis |
| Pennyroyal in flower, freſh | 13 lb. | 6 drachms | Lewis |
| Pepper, black | 2 lb. | 6 drachms | Lewis |
| ——— ——— | 1 lb. | 2½ drachms | Gaubius |
| ——— ——— | 1 lb. | 3 drachms | |
| ——— ——— | 1 lb. | 2½ drachms | Neumann |
| ——— ——— | 1 lb. | 4 ſcruples | Cartheuſer |
| ——— Jamaica | 1 oz. | 30 grains | Neumann |
| Peppermint, freſh | 4 lb. | 3 drachms | Lewis |

Rhodium

| Name of the vegetable. | Quantity. | Weight of the oil. | Maker of the experiment. |
|---|---|---|---|
| Rhodium wood | 1 lb. | 3 drachms | Neumann |
| —— —— | 1 lb. | 2 drachms | Sala |
| —— —— | 1 lb. | 3 drachms | |
| —— —— | 1 lb. | 3 drachms | Cartheuser |
| —— —— | 1 lb. | 4 drachms | |
| Roses | 1 cwt. | 4 drachms | Tachenius |
| —— | 1 cwt. | 1 ounce | Homberg |
| —— | 12 lb. | 30 grains | Hoffmann |
| Rosemary in flower | 1 cwt. | 8 ounces | Lewis |
| —— leaves | 1 lb. | 2 drachms | Sala |
| —— —— | 1 lb. | 3 drachms | |
| —— —— | 3 lb. | $3\frac{1}{6}$ drachms | Neumann |
| —— —— | 1 lb. | 1 drachm | Lewis |
| —— fresh | 70 lb. | 5 ounces | Cartheuser |
| Rue leaves | 10 lb. | 2 drachms | Hoffmann |
| —— | 10 lb. | 4 drachms | |
| —— in flower | 4 lb. | 1 drachm | Lewis |
| —— —— | 60 lb. | $2\frac{1}{2}$ ounces | |
| —— with the seeds | 72 lb. | 3 ounces | |
| Saffron, oriental | 1 lb. | 5 scruples | Cartheuser |
| Sage leaves | 34 lb. | $1\frac{1}{2}$ ounce | Lewis |
| —— in flower, fresh | 27 lb. | 6 drachms | |
| —— of virtue in flower | 1 lb. | $1\frac{1}{2}$ drachm | Vogel |
| Sassafras wood | 6 lb. | $1\frac{3}{4}$ ounce | Hoffmann |
| —— —— | 6 lb. | 2 ounces | Neumann |
| —— —— | 30 lb. | 7 oz. 1 drach. | Dehne |
| —— —— | 24 lb. | 9 ounces | |
| Savin bark | 2 lb. | 5 ounces | Hoffmann |
| —— —— | 29 lb. | 9 ounces | Dehne |
| —— wood | 32 lb. | $\frac{1}{2}$ ounce | |
| Saunders, yellow | 1 lb. | 2 drachms | Cartheuser |
| Scurvy grass in flower, fresh | 6 baskets | 6 drachms | Dehne |
| Smallage seeds | 1 lb. | 10 grains | Neumann |
| Stœchas in flower, fresh | 5 lb. ¾ | 2 drachms | Lewis |
| Thyme in flower, fresh | 2 cwt. | $5\frac{1}{2}$ ounces | Lewis |
| —— —— dry | $3\frac{1}{2}$ lb. | $1\frac{1}{2}$ drachm | |
| —— (lemon) in flower, fresh | 51 lb. | $1\frac{3}{4}$ ounces | |
| —— —— | 98 lb. | $2\frac{1}{2}$ ounces | |
| —— a little dried | 104 lb. | 3 ounces | |
| Wormwood leaves, dry | 4 lb. | 1 ounce | Lewis |
| —— —— | 18 lb. | $1\frac{1}{2}$ ounce | |
| Zedoary root | 1 lb. | 1 drachm | Neumann |
| | 7 lb. | 1 ounce | Dehne |



When

When the quantity of oil inherent in any particular ſubſtance is to be aſcertained, it cannot be done directly on the firſt diſtillation, unleſs water were to be employed for this purpoſe, that is already impregnated with oil; becauſe the water that is diſtilled from an oleaginous body for the firſt time, always imbibes a conſiderable portion of its ethereal oil, and thus renders the calculation erroneous.

Neither are vegetables impregnated with the ſame quantity of oil at all ſeaſons of the year; but herbs ſhould only be applied to this purpoſe when they are in full bloſſom; and many of them, when they are run to ſeed. The roots are moſt impregnated with oil juſt before they ſend forth their radicles in the ſpring, but woods at the beginning of the winter. The maceration of green vegetables is needleſs, and indeed rather detrimental than otherwiſe; whereas, on the contrary, with dry and ſolid bodies, it may be more uſeful; in which caſe ſome common ſalt is added, in order to prevent a fermentation taking place. When freſh vegetables poſſeſs no particular volatile ſmell, it is rather of uſe to let them wither a little. Oils that yield a volatile odour muſt be diſtilled over with a gentle heat; but, on the other hand, ſuch as at the ſame time are diſtinguiſhed by a greater ſpecific gravity, require a ſomewhat ſtronger fire for their diſtillation.

Moſt etherial oils, it is true, ſwim upon the water, with which they have come over the helm in diſtillation; there are ſome, however, that ſink in it. A very good way of ſeparating the former is, having previouſly ſuffered the glaſs filled with the oily water to ſtand at reſt for ſome days, and then by ſhaking it gently, bringing the oil which adheres to the ſides of it, on to the ſurface of the water, to take it of either with a tea-ſpoon, or with a ſmall glaſs ſyringe. The beſt method however of any is to convey it by means of a ſhort and ſlender ſkane of cotton, from the glaſs in which it is firſt received, into another glaſs tied to the upper part of this, by which means, at the ſame time, all the impurities which are frequently to be found in theſe oils, adhere to the cotton, and the oil is obtained pure and clear. With reſpect to the other ſpecies of theſe oils, which ſink to the bottom in water, and are conſequently heavier than water, this latter fluid muſt be made heavier by another body, for which purpoſe, nothing more is neceſſary to be done than to impregnate the water ſtrongly with common ſalt, till the oil which lies at the bottom of the veſſel, riſes to the ſurface, from whence it may then be ſeparated in the manner abovementioned.

As to their *Conſtituent Parts*, it may be affirmed, upon ſufficient foundation, that they conſiſt of *water*, *phlogiſton*, *air*, *earth* and *acid*.

*Water*

*Water* is to be ſuſpected in the compoſition of oils, were it only on account of their fluidity; but it may be proved ſtill plainer, by diſtilling them ſeveral times one after another upon earthy bodies of a calcareous or argillaceous nature, or by burning them under a bell, as has been mentioned with regard to ſpirit of wine. The preſence of *Phlogiſton* can by no means be denied; the inflammability of theſe ſubſtances, and the circumſtance of ſulphur being producible from them by means of concentrated vitriolic acid, as well as from any other phlogiſtic body, is a ſufficient proof of this. *Air* is obtained from them by a degree of heat capable of acting on their compoſition. As to *Earth*, it is to be found in the ſoot, which may be obtained by the combuſtion of them; in the reſiduum of every diſtillation of them by a naked fire; and the coaly maſs that remains after they have been mixed with concentrated witriolic acid, and diſtilled off from it again. The *acid* part is diſcoverable by this circumſtance, that the water which is produced by their gradual decompoſition exhibits plain tokens of acidity; farther, that all theſe kinds of oils act ſtrongly upon copper; and finally, that the fixed alkali from which they have been frequently diſtilled, loſes its acrimony, and acquires the nature of a neutral ſalt*. In etherial oils we find theſe conſtituent parts, it is true, and therefore muſt neceſſarily acknowledge them for ſuch; but it is unknown to us in what manner nature unites them in theſe oils; for it has never been poſſible for the art to compoſe ſuch an oil out of them, where there was none ſubſiſting before. We have only proceeded ſo far as to make divers other ſubſtances enter into an union with an oil already exiſting, by which means its natural quantity has been increaſed, and at the ſame time a change of its former properties effected. In this view I look upon our *Naphthas* or *Æthers* as artificial oils, which have for their baſis the eſſential and etherial oil of ſpirit of wine.

Under this denomination are compriſed certain exceedingly volatile and inflammable oils prepared by art, which may even be inflamed while floating upon the water, and burn upon the ſurface of it till they are conſumed. In a gentle heat they are entirely volatilized without leaving any thing reſinous behind them;

* It ſhould *ſeem* from the experiments of M. *Lavoiſier*, that the conſtituent parts of oils in general were the vegetable principle, inflammable gas and a ſmall quantity of water: As to an acid, when there is any in oil, it appears to be merely the effect of a preceding fermentation, by means of which air being abſorbed, an acid is formed by the union of it with the vegetable principle.

them; they are consequently much more volatile and etherial than all other etherial oils, they are also in some measure of easier solution in water than these latter. At present nine different sorts of æther are known; viz. the Vitriolic, Nitrous, Marine, Acetous, Lignic, Oxaline, Myrmecic, Sebaceous, and Phosphoric, all of which shall now be more particularly described.

*Vitriolic Æther* (Naphta Vitrioli, Aether Frobenii, Oleum Vitrioli dulce, Oleum Vini) was first distinctly described by *Valerius Curdus*, though some vestiges of its having been already observed are also to be found in *Basil Valentine*. It comes over, as has been mentioned above, in the latter period of the distillation of the anodyne spirit, together with a mild acidulous phlegm; but it is best prepared with equal parts of the strongest alcohol that can be procured, and of highly concentrated vitriolic acid. Instead of the ordinary alcohol, alcohol drawn off from French or Rhenish brandy may be employed with more advantage. The acid must be added very cautiously to the vinous spirit at different intervals in small portions, and at the same time the incalescence of the mixture carefully avoided as much as possible. The mixture is then to be put into a retort, and distilled by a gentle heat, till a sulphureous smell is perceived. When the receiver is taken off, the oil will either be directly found swimming upon the phlegm, or it will instantly appear, if some pure water be added to it, upon which the oil is to be separated from the water by means of a glass funnel. The phlegm has a strong smell and taste of this æther, and in fact, still holds a large portion of it in solution. When therefore the quantity of phlegm will repay the trouble and expence of doing it, it may be carefully distilled afresh with some alcohol, in a small retort. But if the quantity is too little, it may be kept till more of it is obtained. Should the æther have acquired a sulphureous smell, it may be rectified over a little lime-water or fixed alkali. It is much better, however, when by this defect having been avoided in the beginning, the rectification becomes unnecessary. This liquor, on account of its extraordi-

principle. With the vegetable principle, in all probability, an additional quantity of phlogiston is combined, which flying off on this occasion, perhaps in union with the hydrophloge of the water, gives an opportunity to the air, the other principle of the water, to unite with its basis. As charcoal is precipitated from oils, according to M. *de Morveau*, by taking the electric spark in them, as well as by distillation and other processes, and all charcoal contains fixed alkali, we must likewise necessarily allow of the existence of a small quantity of fixed alkali in these substances. [E]

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nary volatility, ought to be kept in phials with good ground glafs-ftoppers. It is a very active folvent of feveral refinous bodies, upon which the fpirit of wine has no effect. The refiduum in the retort, may be mixed feveral times more with the fame quantity of alcohol, and be diftilled with the fame intention. The quantity of æther that will be obtained, cannot be determined with any certainty. When the operation is performed in great quantities, and frefh alcohol continually added to the refiduum in fmall portions at a time, and care has been taken to fave alfo the æther which is contained in the phlegm, the quantity of the æther, according to the more recent obfervations of Dr. *Dehne*, may be brought to equal half the fpirit of wine employed in making it*.

* Treatife on the Naphtha of Vitriol, and the Method of preparing it in great quantities, in *Crell's* Chemical Journal, Vol. III, page 108—116. [A]

As they greatly tend to fhew the Nature and Generation of the different kinds of Æther, we fhall give the Reader a pretty copious abftract of M. *Dollfufs's* experiments relative to thefe fluids, as very lately publifhed by him, under the title of *Pharmaceutifch-Chemifche Erfahrungen*, &c. i. e. *Experiments on the Subject of the lateft Difcoveries and Improvements made in practical Pharmacy*, by John Cafpar Dollfufs, 8vo. Leipfick, 1787.

Having mixed 2lb. of vitriolic acid, the fpecific gravity of which was 1,989, very gradually and flowly with an equal quantity of fpirit of wine, he diftilled this mixture by a very gentle fire. The firft ten ounces that came over, confifted of a very ftrong liquor, anodynus Hoffmanni, of an agreeable odour. This he put by apart, marking it A. It was followed by a ftill ftronger æthereal liquor, of which a fmall quantity only would mix with the water; and in order to prevent it from being mingled with any of the fulphureous part, the receiver was changed feveral times. This portion, which amounted to twelve ounces, was marked B. After this he obtained two ounces more C, which however fmelt of fulphur.—He now continued the diftillation with a view ftill more to dephlegmate the vitriolic acid, and obtained three drachms of a thicker kind of æther, fupernatant upon three ounces of a weak fulphureous acid: this *Oleum Vini* was not in the leaft volatile, and nearly of the confiftence of an expreffed oil.

To the remaining dephlegmated vitriolic acid, were added twenty-four ounces of fpirit of wine. The firft feven ounces that came over, were poured to the dulcified fpirit, marked A. Next paffed over ten ounces of a tolerably pure æther, which was mixed with the contents of B: befides two ounces that had a fulphureous fmell, which were mixed with C. And by a repeated dephlegmation of what remained in the retort, were obtained five ounces of a weak fulphureous acid. The remaining acid being again mixed with twenty ounces of fpirit of wine yielded, firft, fix ounces of fpirit, which were put into the bottle marked A. Next, four ounces of pure æther, which was poured into the bottle B. After this, came another ounce, which was mixed with C. The acid was then again deprived of its water to fuch a degree, that it was fcarcely poffible to prevent the whole paffing over into the receiver. He now obtained again four ounces of weak fulphureous acid, upon which floated a little oleum vini.

The

*Nitrous Æther* (naphtha nitri) appears to have been firſt obſerved by *Kunkel*; but as he has given no deſcription of its preparation, it remained unknown for a long

The remainder, which was very thick and covered with a ſlight pellicle, was mixed for the fourth time, with twenty ounces of ſpirit of wine, and yielded five ounces of Hoffmann's anodyne liquor, which was poured into the bottle A: eight ounces of pure æther, which was mixed with B: and at laſt, one ounce of æther that had rather a ſulphureous ſmell. This was followed by a few drops of acid: but the remainder frothed up on a ſudden, and roſe ſo faſt, that to prevent it from going over, the veſſel was obliged to be taken out of the ſand, when an end was put to the diſtillation.

By theſe four diſtillations he obtained from ſix pounds of ſpirit of wine and two pounds of oil of vitriol, twenty-eight ounces of dulcified ſpirit of vitriol, and thirty-eight ounces of æther, which latter, when rectified by being drawn off over manganeſe, yielded twenty-eight ounces of the beſt æther; at the end of this diſtillation were produced thirteen ounces of weak acetous acid. The æther of the laſt portions marked C when rectified by being drawn off over manganeſe, afforded four ounces of very good æther.

The liquor marked D, diſtilled over manganeſe, yielded four ounces of weak acetous acid, and about three drachms of naphtha, perfectly reſembling a diſtilled oil.

The vitriolic acid, uſed in theſe diſtillations, was quite thick and black, and weighed twenty-four ounces. In this acid floated a black powder, which would neither ſeparate by ſubſiding to the bottom nor by riſing to the top. In order to procure this ſeparate, however, he mixed it with eight ounces of water, filtered it through powdered glaſs, and at length collected a black ſubſtance, which conſiſted partly of a powder and partly of grains of different ſizes. He then waſhed it carefully with diſtilled water, but though he had uſed upon the whole twenty-four ounces of water in different portions, ſtill the powder had an acid taſte. It felt very fine between the fingers, and when dry, weighed twenty-one ounces: it was inſoluble in acids, and the ſtain it left upon paper reſembled that made by Indian ink.

With a view to the better inveſtigation of this ſubſtance, half an ounce of it was diſtilled in a ſmall retort. The diſtilled liquor weighed a drachm and a half, and proved to be very weak acetous, mixed with a little ſulphureous acid. The reſiduum was a black coal, which burned in the open fire, and required to be calcined for the ſpace of a quarter of an hour before it was reduced to aſhes. The aſhes weighed twenty-five grains, and were found to conſiſt of ſelenite, calcareous earth, and a little murioecic earth. A drachm of the ſame black matter digeſted with nitrous acid, which was afterwards diſtilled off from it, and then diluted with diſtilled water and filtered, yielded on cryſtallization, a few cryſtals, which proved to be the pure acid of tartar. The inſoluble earth that was left behind was ſelenite.

On rectifying the vitriolic acid, freed from its black matter, and diluted with eight ounces of water, he obtained, firſt nine ounces of ſulphureous acid; which was followed by one ounce of

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a long time after, till at length, in the year 1740, it was re-diſcovered by *du Hamel*, and afterwards more particularly elaborated and deſcribed by *Navier*, *Sebaſtiani*, and

an acid that was rather high-coloured, and now the vitriolic acid followed quite colourleſs. This he diſtilled to dryneſs, and in the whole obtained about nineteen ounces and ſix drachms of vitriolic acid, the ſpecific gravity of which was 1,723.

Attending to this conſiderable loſs of the vitriolic acid, he put to himſelf the following queſtion: How and in what manner does the vitriolic acid affect the ſpirit of wine; and is any part of the acid received into the compoſition of the æther? For the ſake of reſolving this difficulty, he made the following experiment.

Two pounds of vitriolic acid, of the ſame gravity as the former, were diſtilled with ſix pounds of highly rectified ſpirit of wine. The firſt twelve ounces that came over were ſpirit of wine, almoſt totally unchanged. Next followed about two ounces that ſmelled a little of æther; and after this two pounds, of which about one-third was æther. When about five pounds had been taken, the liquor that came over began to ſmell ſomewhat ſulphureous. However, he drew off about nine ounces of it; when the vitriolic acid began to ſwell and riſe in ſuch a manner, that he was obliged to take the retort out of the ſand; he then filtered this acid through pounded glaſs, and ſubmitted it to diſtillation. The three firſt ounces were a weak ſulphureous acid; then followed one ounce of a more concentrated red acid, and next, another ounce of a yellow caſt; when all the reſt paſſed over quite colourleſs. The whole weighed twenty-ſeven ounces, and the ſpecific gravity of it compared with that of diſtilled water, was, as 1,6670. to 1,0000. The coaly matter, waſhed and dried, weighed ſeven drachms and a half.

From theſe facts the author draws the following concluſions; That as the firſt portions of this mixture paſſed over in the form of ſpirit of wine totally unchanged, the action of the vitriolic acid upon the vinous ſpirit takes place only in conſequence of its acid's retaining the ſpirit in a much greater degree of heat, than this latter would bear under the mere preſſure of the atmoſphere; and as the acid comes into contact with every particle of the vinous ſpirit, the vegetable acid in the latter is partly converted into coal, and partly ſeparated in the form of vinegar; while the more oily part of the ſpirit of wine being now diſengaged, combines with the vitriolic acid, and gives it the form of a very ſubtile ſoap or æther. After this æther is come over, that part of the vegetable acid, which, when it was diſengaged, met with water enough to prevent it from being changed, follows under the form of a weak ſulphurated acetous acid. Theſe concluſions, adds the author, receive additional ſtrength from the conſideration that the vitriolic acid did not ſeparate ſo much carbonaceous matter from the ardent ſpirit, when the ſix pounds were added at once; and that the diminution of this acid was leſs in the ſame proportion, as was alſo the generation of æther.

Theſe concluſions, founded upon analyſis, he ſubmitted to the following trial by ſyntheſis:

One ounce of vitriolic æther being expoſed to the air in a ſhallow veſſel, left one drachm and eight grains of water impregnated with vitriolic acid, on the ſurface of which floated a few drops

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and many others. It is prepared from the ſtrongeſt alcohol, and the ſtrongeſt ſmoaking ſpirit of nitre; in this operation however many circumſtances occur, which ought to be attended to; and what is more particularly remarkable is, that this oil is produced without diſtillation from the mere commixture of the two liquors. Generally to two parts of alcohol are added, by intervals and in very ſmall portions of a few drachms each, one part and a half of ſmoaking acid of nitre, and then put by for ſome days in a cool place in a well-ſtopped bottle. After this period the æther will be found ſeparated upon the ſurface, and muſt be immediately drawn off with a glaſs funnel. The remaining liquor may ſtill be mixed with eight parts of alcohol, and the dulcified ſpirit of nitre diſtilled from it. In order to perform this operation with the greateſt ſafety, the proceſs of Dr. *Dehne* is adviſable, and the mixture muſt be made in a glaſs tubulated retort, to which a large receiver is luted. This ingenious chemiſt put two pounds of alcohol into a retort, and added to it, every four hours, half an ounce of ſmoaking ſpirit of nitre drop by drop. Twelve ounces of the ſpirit having been introduced in this manner into the retort, and half an ounce more being added, the mixture began to throw up ſmall bubbles, though without producing any heat; twelve hours however elapſed before all was quiet again. By this means came over into the receiver about an ounce of æther, which, on the farther addition of nitrous acid, received an increaſe. After this two drachms only of the acid were added morning and evening. On the eighth day after the firſt addition, a greeniſh æther was ſeparated to the depth of about half a finger; but the addition of ſpirit of nitre was conſtantly continued, till on the twelfth day one pound and five ounces of nitrous acid had been introduced into the receiver. The mixture then began to be affected with a briſker motion, when the æther was taken off, which weighed one pound and an ounce. Upon the reſiduum, two drachms of nitrous acid were poured drop by drop as before, morning and evening, till the acid

of ol. vini. He conſidered this experiment however as fallacious; as the æther in its eſcape volatilizes part of the acid, and carries it off along with it. He then thought that a ſolution of lead in nitrous acid might anſwer his purpoſe better, as the nitrous acid readily combines with the phlogiſticated part of the æther, and the diſengaged lead falls to the bottom, in union with the vitriolic acid. To two ounces of æther therefore he put half an ounce of the ſolution of lead, and diſtilled this mixture in a retort. Firſt appeared ſome æther unchanged, then ſome water that ſmelled of nitrous æther. In the retort was a ſmall quantity of vitriol of lead, the weight of which he did not attempt to aſcertain, as the æther was not wholly decompoſed. [E]

fell to the bottom in the form of bubbles, which had a perfectly green appearance. Dr. *Dehne*, in consequence of much experience affirms, that these bubbles are a sign, that no more æther will be separated from a mixture of this kind by the farther addition of nitrous acid; but that the mixtute is rather saturated with acid, and is not capable of yielding fresh æther unless fresh spirit of wine be added to it. This second time were separated eight ounces and three drachms of æther, so that in all one pound ten ounces and three drachms of nitrous acid were mixed with two pounds of alcohol, and from this quantity one pound nine ounces and three drachms of æther were obtained. The residuum still weighed one pound twelve ounces, and five ounces were lost in the whole. It was probably æther, in which case the weight obtained would be still more increased. This operation succeeds best in the coldest weather. It has also frequently been observed, that spirit of wine, distilled from oily bodies, yields more æther than when it is pure. This æther, in the state in which it is obtained, is commonly still acid, and must be deprived of its acid by a solution of alkaline salt. In fine, it possesses so great a degree of elasticity that it will sometimes burst the bottle; therefore, by way of precaution, it had better be kept in a cellar, parted into small phials *.

*Marine*

* Mr. *Dollfuss*'s Experiments on this subject, as related in his *Erfahrungen*, &c. deserve a place here, and are as follow:

1. On four ounces of perfectly dry nitre was poured a mixture, consisting of two ounces of oil of vitriol, and four of spirits of wine; the whole being submitted to distillation, the first six drachms that came over were dulcified. These, being set aside, were followed by three ounces more, which, on being rectified with water and salt of tartar, yielded two ounces of æther.

2. In imitation of M. *Fischer*, (vid. *Crell*'s Neueste Entdeck. part 5.) upon two ounces of concentrated nitrous acid were poured six drachms of weak spirit of nitre, and upon this, three ounces of spirit of wine. The mixture was now suffered to stand undisturbed, and the phial loosely corked. In the space of a day or two the whole of the lower part appeared homogeneous, and the æther was formed at top. The whole was now put into a retort, when two ounces and one drachm of very pure æther, which neither affected the blue juices of vegetables, nor the tincture of gum guaiacum, were obtained. The residuum seemed to be entirely free from nitrous acid, and was found to be vegetable acid, consisting partly of the acid of sugar, and partly of an imperfect vinegar. The author here asks, what is become of the nitrous acid? There was but very little, says he, in the residuum. This circumstance is therefore a confirmation of the idea I threw out just now, viz. that the acids contribute the most to the formation of æther; that the spirit gives out its acid as water, and the other more subtile and phlogistic part incontinently combines with the mineral acid, and phlogisticates it, in order to constitute the æther with it.



3. Into

*Marine æther*, or the naphtha of common ſalt, is of all others the moſt difficult to prepare; becauſe the marine acid in its pure ſtate cannot be concentrated to the degree that in general is requiſite for the preparation of æther. Beſides, there is this circumſtance, that it is with the greateſt difficulty that this acid, chemically unites with combuſtible bodies. The ſucceſs however cannot be doubted of; as even ſo antient a chemiſt as *Glauber* mentions, that he had obtained this æther. The Marquis de *Courtanvaux* alſo acquired it by diſtillation, from the ſmoking ſpirit of *Libavius*, mixed with twice the quantity of alcohol. Likewiſe a Chemiſt at Copenhagen of the name of *Muhlenſtedt*, has not long ſince aſſured the public, that he has prepared it from this ſame ſpirit; and Profeſſor *Kratzenſtein*, of the ſame place, has publicly confirmed this aſſertion, and adds, that it ſuſtained the requiſite teſt with cauſtic ſpirit of ſal ammoniac, and that from one ounce and a half of what appeared to be naphtha, one ounce of real naphtha remained. He appears to place the manœuvre neceſſary for the raiſing of the fire towards obtaining it in the end of the operation. The Baron de *Bormes* aſſerts, that he has obtained it in the following manner. In twelve pounds of ſpirit

3. Into a tubulated retort, containing three ounces of ſpirit of wine, he put, drop by drop, a drachm of concentrated nitrous acid, and this he repeated till the quantity amounted to two ounces. Diſtilling this mixture by a very gentle fire, he obtained two ounces and a drachm of æther; the reſiduum weighed two ounces. This again he diſtilled to one half, and obtained one ounce of a weak acetous acid; he then poured ſome more nitrous acid on the remainder, in order to promote the cryſtallization of the ſaccharine acid, and obtained one drachm and fifteen grains of this acid, mixed with an ounce of an imperfect vinegar.

4. He attempted to make nitrous æther, in M. *Tielebein*'s method, by pouring ſtrong nitrous acid upon ſpirit of wine at once in a very great degree of cold, but with very ill ſucceſs, for the bottle burſted in a ſhort time after the mixture had been made. (In this method the ingredients are kept in the ſnow for twenty-four hours, previous to their mixture, and during their mixture a ſtill ſmaller degree of cold is artificially generated on the external ſurface of the veſſel.)

5. He likewiſe diſtilled a mixture of nitre and oil of vitriol, and received the vapours and drops in a receiver, in which was contained ſpirit of wine. This method, though it ſucceeded very well with him, yet as dangerous accidents have happened to others who have adopted it, he by no means adviſes to the Chemical Tyro.

In order to get a good nitrous æther, by the firſt diſtillation, he adviſes the chemiſt to diſtil four parts of nitre of mangancſe, four of vitriolic acid, and eight parts of ſpirit of wine. All ſpirit of nitre or nitrous æther, however dulcified they may be at firſt, will develope their acid after having been kept for ſome time, (in conſequence of the air inſinuating itſelf into the bottle and combining with the vegetable baſis.) To prevent this, a little dry alkali muſt be put into the bottle in which it is kept, in order to combine with the acid as ſoon as it is diſengaged. [E]

of salt he dissolved as large a quantity of flowers of zinc as he possibly could, by means of digestion. From the solution, poured off clear, he next distilled about three-fourths of phlegm in a retort, after which remained a thick liquor of the colour of gold. With this having mixed six pounds of alcohol, he kept the mixture in digestion for the space of eight days, when he filtered it, and put it into a retort, in order to distil it. In the beginning of the process an inflammable spirit was obtained, but afterwards oily striæ appeared, and then the receiver was changed. The distillation of the liquor being continued to dryness, the æther was at length obtained and separated, of a yellowish colour and a pungent smell. But this æther is best obtained in *Westrumb*'s method, from four ounces of common salt, two ounces of oil of vitriol, and two ounces of pulverized manganese, together with six ounces of alcohol, by means of distillation. The liquor being distilled to dryness, is poured back upon the residuum, and distilled afresh. In this distillation, nearly the half, which comes over first, will be dulcified spirit of salt, and the greatest part of the other half marine æther, which may be separated from the rest by the addition of water *.

*Acetous*

* Neueste Entd. in der Chemie. Vol. VIII. p. 28—54, Vol. IX. p. 68—79. [A]

Mr. *Dollfuss*, l. c. after examining the various methods of making marine æther and dulcified spirit of salt with the muria either of antimony or of zinc, gives it as his opinion, that for the purpose of combining the marine acid the better with the spirit of wine, the phlogistication of it may be better effected by the means indicated in the following experiment. Four ounces of digestive salt, previously well dried, were mixed with two ounces of manganese, and put into a retort. Upon this powder was poured a mixture of five ounces of spirit of wine, and two of vitriolic acid, which was distilled, and the first five ounces and a half poured back again upon the residuum, when the whole was drawn off slowly by distillation. The spirit of salt, thus obtained, had a very penetrating agreeable odour, somewhat resembling that of nitrous æther; and at first, swam upon the top of the water; but mixed with it at length, by long continued agitation Towards the end of the distillation he obtained a little oil which did not mix with the water; by the addition of four ounces more of spirit of wine, he obtained more of the dulcified spirit of salt. As the manganese was not quite white, it was not wholly phlogisticated. (*Less of it therefore would have sufficed.* E)

In the year 1782, reflecting upon the theory promulgated just before that period in *Crell's Chemical Journal*, relative to the various æthers containing the acid, with which they were prepared, the editor of these sheets was first struck with the idea that these very volatile substances, instead of being composed of the acids used for their preparation, were composed of the bases only of those acids: Last year, viz. 1786, this idea was in a great measure confirmed to his mind by some

*Acetous Æther*, or the *Naphtha of Vinegar* (Naphtha aceti) was first prepared and made public by the Count *de Lauraguais*. A description of it is also found in Professor *Spielmann's Institutes of Chemistry*. For this purpose, according to *Westendorf's*

some hints thrown out by M. *Dollfuss* in the Chemical Annals relative to this subject, as well as by M. *Hermbstadt's* Experiments, published some time before, under the title of *Physiche Chemische Versuche*; but seems to have attained absolute demonstration by means of the preceding observations on the preparation of the mineral æthers.

In fact, it must be evident to every one that reads them, that in the generation of these æthers, an exchange takes place between the basis of the mineral acid and that of the vegetable acid in the spirit of wine; the former attracting the phlogiston of the spirit, and giving out the pure air contained in it, which uniting with the vegetable basis of the latter, forms acid of tartar and vinegar. We must observe however that it is not a soap, but an oil that is produced in these cases: as all æthers consist of the same general principles as other oils, both expressed and essential, though in different proportions, viz. phlogiston, water, and the basis of some acid, not the acid itself; for that, before the process of rancidity takes place, is to be found in no oil whatever. The mineral æthers then are not improperly called *Naphthæ* by the Germans, as they consist of exactly the same principles as the natural naphthæ or the finer kinds of rock oil, which are more generally known by this name.

As the æthers are composed, so they may be decomposed, by double elective attraction. This would have been fully proved by the last experiment made with the vitriolic æther, had the nitrous solution of lead been employed in a greater proportion: as then, the nitrous acid supplying pure air to the vitriolic basis of the æther, more vitriol of lead would have been obtained, and the æther, (instead of being partially, as it was here) would have been completely decomposed.

It does not appear probable that spirit of wine contains any tartar or acid of tartar, ready formed: but rather, that the tartar found here is formed by the aerial part of the vitriolic acid combining with the imperfect acid or vegetable basis of the spirit, in too small a quantity for the compound resulting from it readily to unite with water: whereas in the formation of vinegar, the contrary circumstances may be observed to take place.

It is likewise worthy of notice that the liquor marked D. (in the experiments upon vitriolic æther) when distilled over manganese, i. e. combined with pure air, not only formed a perfect æther, but yielded vinegar besides: the pure air completing the separation of the vegetable basis from that of the vitriolic acid, and throwing it off as vinegar; and thus giving an opportunity to the latter to unite with the phlogistic part of the compound, and form a pure vitriolic æther.

Finally, we see in the first operation for making vitriolic æther, that when air is supplied by manganese (or otherwise) the vegetable principle is made miscible with water, and is converted into vinegar. Thus the æther is *rectified*, i. e. freed from the vegetable principle adhering to it, by the admixture of the air of the manganese with this principle; and, as hence it acquires solubility in water, a perfect separation takes place: for the air from the manganese seizes that principle

*Westendorf's* recipe, equal parts of the ſtrongeſt ſpirit of vinegar and alcohol are mixed together, and ſuffered to ſtand for ſome days in a well-ſtopped glaſs, till the mixture has acquired a particularly agreeable ſmell. Upon this the liquor is poured

principle or baſis which is moſt looſely combined, which in this caſe is the vegetable: the vitriolic principle being now pretty firmly united with the phlogiſton of the ſpirit, is therefore left untouched by the pure air.

Soon after writing the above, viz. towards the end of laſt year (1787) having peruſed M. *Lavoiſier's* excellent analyſis of ardent ſpirit, publiſhed in the Journal de Phyſique, it was impoſſible to withhold one's aſſent to the reaſonings and experiments by which he has demonſtrated the preſence of inflammable gas in that fluid. The æthers then may be ſaid to be compoſed of this gas united with the baſis of ſome acid, and a very minute quantity of water; or, to ſpeak more accurately, of hydrophloge combined with the baſis of an acid and phlogiſton, a very ſmall quantity of the vegetable principle, and a very minute portion of pure air: for in theſe, as well as in all other fluid oils, water does not ſeem to exiſt ſeparately; but its hydrophloge, on the one hand, united with phlogiſton and air, forms a ſubſtance that may be ranked between inflammable gas and water; and, on the other, its air being alſo looſely combined with the vegetable principle, forms a ſubſtance which is neither water nor acid, but between both.

That æthers ſtill contain a portion of the vegetable principle, the coal left by them after combuſtion, and the aerial acid into which they are convertible by evaporation, evidently demonſtrate.

The *Oleum vini* has not yet been properly analyſed. It would be well worth while however to ſee, in the method practiſed by Meſſrs. *Lavoiſier* and *Berthollet*, whether its baſis be the vegetable principle or that of the vitriolic acid.

The French academicians ſuppoſe, that in making vitriolic æther, air is taken from the vitriolic acid by the vinous ſpirit, which is true; but not attending to the vinegar that is formed in this proceſs, they proceed to affirm that this air becomes one of the principles of the æther, (vid. *Fourcroy*, Vol. IV, page, 160). M. *Berthollet*, indeed, in his laſt paper on this ſubject (Mem. de l' Acad. des Sc. pour 1785) takes notice of the formation of the vinegar, and upon the whole approaches nearer than he did before to the doctrine laid down in theſe notes: concluding that æther is an oil ſeparated from ſpirit of wine, and combined with a large quantity of inflammable gas, and a little of the acid employed in its production.

The æthers being compoſed of hydrophloge, phlogiſton, air in a very ſmall quantity, and the baſe of the acid employed in their preparation, it is probable that nitrous æther differs very little from nitrous gas, otherwiſe than by the hydrophloge and vegetable principle it contains. And perhaps the caſe is ſimilar with reſpect to vitriolic æther and vitriolic acid—(or rather ſulphuroxyc) gas, and ſome other æthers.

The æthers appear to contain leſs pure air than ardent ſpirit, and ardent ſpirit leſs than water. Their extreme volatility may poſſibly proceed from the large portion of inflammable gas contained in them.

Nitrous æther is beſt made in very cold weather; as the oil is not then ſo miſcible with water, and ſeparates as faſt as it is formed, without any of it being reabſorbed. It is made without heat, becauſe

poured into a retort, to which a receiver is accurately luted, and nearly the half of it drawn off by diftillation, with a gentle heat. To the diftilled liquor is next added a fixteenth part of pure falt of tartar, diffolved in four times its quantity of water, and the liquor gently agitated with a circular motion, when the æther will immediately feparate from it, and float upon the furface of it, like oil; the quantity of which commonly amounts to one half of the alcohol employed in the procefs: the æther is then taken off. To the vinegar that remains in the retort half the quantity of alcohol may be added once or twice more, by which means ftill more of this æther may be obtained. From the remaining phlegm, from which the oil has been feparated, there may yet be diftilled a *liquor anodynus vegetabilis* *. The chief condition on which the naphtha of vinegar is to be obtained, confifts, according to *Scheele*, in the prefence of a fmall quantity of a mineral acid of any kind whatever †.

*Lignic*

becaufe the nitrous gas of the nitrous acid is extremely volatile, and therefore, when once feparated from the vinous fpirit, eafily flies off.

With refpect to marine æther it muft be likewife obferved, that M. *Weftrumb* has fince denied the poffibility of making it, either in his own or any method whatever; as he contends that the product of any of them is not a genuine æther that fwims on water, but a mere dulcified fpirit: though it muft be confeffed, that he has not abfolutely invalidated the teftimony of *Courtanvaux* and *Scheele*, and many other Chemifts who employed the fpiritus fumans likewife in this procefs; as he made ufe of butter of tin for this purpofe. If M. *Weftrumb's* affertion be true, it will go to prove that the marine acid will not part with its bafe pure and entire to ardent fpirit, even when affifted by pure air. [E]

* After a few lefs fuccefsful experiments, M. *Dollfufs* hit upon the following method: Eight ounces of fugar of lead are to be expofed to a very gentle heat, by which means the falt will lofe part of its water of cryftallization. It will then weigh five ounces fix drachms. In this ftate it to be put into a glafs retort, and a mixture confifting of five ounces of vitriolic acid and eight ounces of fpirit of wine is to be poured upon it; when the whole is to be diftilled by a very gentle fire. The firft ounce that paffes over, will be found to be dulcified acetous acid; the next ounce will be almoft all of it æther: after this the æther comes over in its pureft ftate.

The æther obtained by this diftillation will be found to weigh three ounces and fix drachms.

† The fuccefs of this operation does not appear to depend on the prefence of any mineral acid whatever; but on that of pure air: for it is to be obferved, that when our author fpeaks of the *ftrongeft* acetous acid, he always means the *aerated* acid. All the following æthers, except the febaceous and oxaline, having been formed of acids expelled either by the vitriolic or nitrous acid, we cannot help concluding that they were in the fame predicament.

With

*Lignic Æther*, or the Naphtha of Vinegar of Wood, which was firſt made public by *Goettling*, is indiſputably, of all the æthers, the moſt worthy of notice; as it throws the cleareſt light on the origin of theſe oils. For this, the moſt concentrated vinegar of wood is requiſite, which may be procured in the ſame manner as the abovementioned concentrated acetous acid. For this purpoſe, an empyreumatic vinegar of wood is firſt of all to be diſtilled from beech-wood, and afterwards rectified by another diſtillation. About three pounds of it are then to be ſaturated with purified alkali, to do which I found it took five ounces. The ſalt evaporated to dryneſs, is next ſuffered to fuſe by a gentle heat, and diſſolved in water. The lixivium being evaporated and filtered, yielded me three ounces and two drachms of a ſalt, which reſembled terra foliata tartari. To this I added two ounces of oil of vitriol, and diſtilled off the concentrated acid of wood in it, which weighed one ounce ſix dracms. This I mixed with the ſame quantity of alcohol, and diſtilled it in a ſmall retort; it yielded two ounces and one drachm and a half of a genuine naphtha of vinegar of wood; and conſequently a greater weight than that of the alcohol I had employed.

*Oxaline Æther*, or Naphtha of ſalt of Wood-ſorrel, was firſt obſerved by *Savary* on mixing and diſtilling equal parts of alcohol and pure acid of ſalt of wood-ſorrel, which he drew off from this ſalt by diſtillation without any farther addition. From the mixture of one ounce of each he obtained three drachms of æther.

*Bergman* has likewiſe obſerved the production of æther of ſugar *. From equal parts of cryſtallized ſaccharine acid and alcohol, were obtained by diſtillation, firſt ſpirit of wine, and then an acid liquor, which by evaporation, yielded cryſtallized ſacharine acid, and with lime-water let fall a ſacharine ſelenite; on the top there floated a thin ſtratum of æther, which was tinged blue by calx

With reſpect to the Sebaceous acid, which is obtained by ſimple diſtillations, M. *Berthollet's* recent diſcovery relative to fat, viz. that it contains a portion of pure air, may induce us to ſuppoſe that this acid exiſts in general in the aerated ſtate. As to the Oxaline acid, the difficulty vaniſhes entirely, when we reflect that this and the acid of Sugar, however procured, are one and the ſame acid.—That all theſe acids contain a redundant portion of pure air, cannot perhaps be aſſerted: but it is far from being improbable that part of their air adheres ſo looſely to them, that they are eaſily deprived of it by the double elective attraction that takes place in theſe inſtances. [E]

* This is in all probability the ſame with the preceding. We have therefore comprehended them both under the denomination of *Oxaline* Naphthas or Æthers.

calx of copper, and, after it had been previously heated, but not till then, was set on fire and burned with a blue colour.

According to Professor *Crell*, *Sebaceous æther*, or the *Naphtha of fat*, is extracted by a gentle heat from equal parts of alcohol and acid of fat, after the mixture has been kept in digestion for the space of half a day. A mixture of half an ounce of each yielded three of æther. Under the same circumstances an *Æther of urine* (or rather phosphoric æther) is mentioned by Dr. *Westendorf*, which was distinguished by a smell like that of quinces. For this purpose he employed the acid which was expelled from the crystallized salt of urine, by means of oil of vitriol. M. *Bucholtz* prepared a myrmecic æther from equal parts of alcohol and concentrated acid of ants, which he first concentrated with fixed alkali, and afterwards detached again in the strongest state by means of oil of vitriol*.

These artificial oils are probably produced by the combination of the acid employed with the æthereo-oleaginous part of the spirit of wine. With these unites a certain part of the different acids, (undoubtedly the most volatile and fine) in such a manner, that it is taken up and enveloped by the oil of the spirit of wine, by which means it loses its acid taste, and its miscibility with water, and for this reason, consequently, augments in appearance the quantity of the oil in proportion as the acid is more or less disposed to combine with it. The more homogenous the acids are to this oil, the better they may be united with it. This seems to explain the reason, why spirit of wine, charged with a greater quantity of

It should also be observed that, although these æthers, especially those made with the mineral acids, resemble in every respect the natural Naphthæ, and appear to consist of the same constituent parts, yet for the sake of precision, it is better not to confound them, as the German writers generally do, under the same denomination; but distinguish these artificial oils by the name of *Æthers*, applying the w rd *Naphtha* to those that are produced by nature only.

It appears highly probable, that the native Naphthas owe their origin to the decomposition of vegetable oils by the vitriolic acid; and that this may likewise be the case with some other bitumens. Neither is it unlikely that the sulphur found in vegetable and animal substances, sometimes proceeds from a double decomposition of this kind, assisted by fermentation. Finally, this opinion receives additional force from the consideration, that vitriolic acid has lately been given internally with success for the cure of the itch; and from its operation in destroying the insects which are the cause of this disorder, as well as from the sulphureous smell of the transpirable matter of the patient, it is evident that this acid has been converted into sulphur by a similar process, the blood in living animals being undoubtedly in a state of fermentation. [E]

* Vid Neueste Entdeck. in der Chemie, Vol. VI, page 55–72. [A]

etherial

etherial oil, alſo yields more naphtha; why the oily acids of wood and of fat produce the greateſt quantity of all; and why the quantity of æther of vinegar of wood is even greater than that of the ſpirit of wine which has been employed; and, laſtly, why the quantity of the æthers is very much diminiſhed by alkaline ſalts: nay, by frequent abſtraction from alkali, the whole of this compoſition is deſtroyed, and their quantity reduced again to the original of the æthereal oil of the ſpirit of wine. Æthers therefore, in my opinion, are etherial oils compounded afreſh by art, of which the natural etherial oil of the vinous ſpirit conſtitutes the baſis. From the action of the acid upon this oily part, ariſes the volatile ſubtle ſmell, which is peculiar to each kind of æther, and by which one may immediately diſtinguiſh from what acid the æther has been prepared. But if the acid acts too ſtrongly upon it, the ſmell will alſo increaſe the more; as occurs in the vitriolic æther that comes over quite at the end of the operation, and which by this means becomes very ſulphureous, and at the ſame time thicker and heavier than it was before. But as ſoon as the acid is ſeparated again from it, all theſe changes are at once removed.

Some Chemiſts are of opinion that the production of the æthers is the mere reſult of an intimate combination of the acids with the whole of the ſpirit of wine. But if this were the caſe, the quantity of theſe æthers would always be greater than that of the ſpirit of wine employed; whereas, on the contrary, in moſt caſes it amounts to much leſs; and farther, when the acid is ſeparated from æther, ſpirit of wine ought to be reproduced; but neither is this the caſe, a very ſmall quantity only of a leſs volatile oil, viz. *oil of wine* being obtained from it. It is therefore more probable that the production of the different æthers is founded upon the decompoſition of the ſpirit of wine, and that in this operation from its etherial oily parts, together with the acids employed, a new volatile, ſulphureous, oily combination of a different nature, ariſes.

The particular properties of the *native Æthereal Oils*, ſuch as taſte, ſmell, colour, conſiſtence, gravity, and certain other relative qualities, remain now to be mentioned, and the moſt remarkable circumſtances reſpecting them, pointed out.

The *Taſte* in each of theſe oils is peculiar to it, and preciſely the ſame with that of the ſubſtance from which the oil was extracted. Some have a ſaccharine taſte, as the oils of aniſeed and fennel; others a hot, fiery taſte, as thoſe of ſavoury, them and cloves; ſome taſte like camphor, as thoſe of peppermint, cajaput,

and roſemary; ſome taſte bitteriſh, as oil of wormwood; and, laſtly, ſome have quite a mild taſte, as the oils of juniper, roſes and pepper. In ſome the taſte is much ſtronger before their ſeparation from the ſubject; e. g. in the oils of cloves and pepper; this proceeds from certain gummy or reſinous particles, in which, properly ſpeaking, reſides the ſtrong acrid taſte, and which remain behind in diſtillation. In others, on the contrary, the taſte is ſtronger after diſtillation than when they were in their natural ſtate of combination with the ſubject. The oil of lemons does not taſte ſo acid and hot while it is yet in the peel, as it does when it has been preſſed from it; becauſe in the peel the oil is ſtill mixed with aqueous and mucilaginous particles, which diminiſh its acrimony. The taſte of oils in general ſeems to depend on a peculiar ſaline compound.

In each of theſe oils the *odour* is different, but cannot be deſcribed. It ſeems to depend upon a volatile etherial matter; becauſe, after ſome years are elapſed, during which time it probably makes its eſcape, the ſmell is entirely altered, no loſs is perceptible in the quantity of the oil. To avoid this inconvenience, though theſe oils ought to be kept in bottles ſtopped with the greateſt care.

The *Colour* is likewiſe very different in different oils. Some are perfectly limpid, like water; moſt of them are yellowiſh: the colour of ſome is brown; of others, green; and of others again, a fine blue. The colour of the oils of roſemary, juniper-berries and turpentine, is quite *white*. The oils of cajaput, ſaſſafras, cinnamon, cloves, and moſt of the other oils of this kind, are of a *yellowiſh* colour. The colour of the oils of thyme, Spaniſh hops, and zedoary, is *browniſh*. The oil of wormwood is *brown*. A *blue* colour is peculiar to the oils of common camomile flowers, the flowers of milfoil, of pimpernel-root, of gum, or rather the reſin of galbanum, and, according to a late obſervation, alſo of the herb Arnica (Arnica Montana L). All theſe colours, however, are liable to be changed by a variety of circumſtances, among which are to be reckoned the ſoil, climate, age, change of ſeaſons, and the degree of heat applied in the diſtillation.

With reſpect to their *conſiſtence* or degree of fluidity, the following differences are obſervable. Some are as liquid as water, and are not alterable by cold. Others, though naturally alſo very liquid, are inſpiſſated by cold; e. g. the oils of aniſeed, fennel-ſeed, and partly the oils of ſaſſafras and parſley-ſeed. Others, immediately on being diſtilled, come over the helm of a thickiſh conſiſtence: of which we have inſtances in the oil of roſes, of elecampane, of the leaves of the

the lauro-cerasus, or mock-laurel, and also, according to *Gaubius*, in the volatile butter of nutmeg.

With regard to their *Gravity*, it is in general to be observed, that most of them float upon water, and consequently are lighter than this fluid; a few only sink to the bottom in it, and thereby prove that they are heavier than water. Of the latter kind are the oils of cloves*, of the flowers of cinnamon, of the bark of cinnamon, of sassafras and of yellow sanders.

There is also a considerable difference perceivable in the oils, with regard to their *solubility* in spirit of wine; they are all indeed soluble in spirit of wine, but not in the same quantity, and with the same readiness. Some are dissolved in an equal quantity of spirit of wine; others require two, four, six, or even eight times their weight of this menstruum; some are taken up immediately on being mixed with it, others require some degree of heat. In their mixture with concentrated vitriolic acid, some produce more heat, effervescence, vapour, colour, and inspissation than others, by which the proportion of their phlogistic component parts, may in some measure be ascertained. Some, on being mixed with highly concentrated nitrous acid, break out into open flame, as the oil of cloves and sassafras; others, on the contrary, do not †.

The small quantity, which most of them can be extracted from a large number of the bodies contained in them, and the high price at which, in consequence of this, they are rated, has long ago occasioned the quantity of these oils to be increased by means of cheap additions, or, in other words, the oils themselves to be

* As on account of the weight of the oil of cloves much of it is lost, if the distillation be not carried on properly, Mr. *Dollfuss* proposes the following method of distilling it. Any quantity of cloves ad libitum is to be put into a glass retort. This retort is to be placed upon a ring made of loam or ordinary clay, and fixed in a common distilling pot; so that it may not touch any part of the pot. Upon this distilling pot, another of the same shape is to be placed; so that the retort is no where exposed to the air, and that the heat is equally distributed to every part: a receiver being adopted to the retort, the fire is to be put under this apparatus, which is to be constantly kept at an equal pitch through the whole of the operation; first will appear some watery vapours, after which, the oil will exude out of the cloves, and be collected in the neck of the retort. [E]

If this distillation be performed with proper attention, two ounces and five or six drachms will be obtained of pale and colourless oil of cloves of the best sort.

† Concerning the conversion of oil of aniseed into a peculiar crystalline substance by means of nitrous acid, vid. *Francis Charles Achard's* Chemisch-Physische Schriften. Berlin, 1780, page 23—33. [A]

adul-

adulterated. This may arife from two caufes; firft, merely from the covetoufnefs of the vender; and then it is certainly an illicit act: but this bad practice may alfo have been introduced by the ignorance and covetoufnefs of the buyer, who fometimes will peremptorily infift upon having them at a lower rate than the genuine commodity can be fold for. Both cafes occur very frequently in our times; and, on account of the latter, we are now and then obliged ourfelves to imitate this bad practice. But I mention it here exprefsly for the fake of marking out the proper limits in this cafe, that this practice is abfolutely an impofition, *when ordinary adulterated oils are fold for a price which ought only to be paid for the genuine.* On the other hand, thofe that do not chufe to pay this price, muft even take things as they find them. Without giving a defcription how this augmentation is to be effected, I fhall rather, for the fake of thofe who wifh to have genuine effential oils, and pay a fair price for them, mention the manner in which they fhould be tried, in order that the unfufpecting chapman may not be defrauded of his money, and the views of covetous dealers be fruftrated. 1. When an effential oil is mixed with water, and the latter fluid becomes turbid and milky, and at the fame time the quantity of the oil is fomewhat diminifhed, it is not pure. 2. When a few drops of it are let fall upon a fheet of paper, and held over a hot ftove, or over an open fire, and a greafy fpot remains on the paper, it is a fign that it has been mixed with fome expreffed oil. Such an oil alfo will diffolve only partly in fpirit of wine; but when, 3. a few drops of fuch oil being let fall upon a fheet of paper evaporate, and at the laft a fmell is perceived different from that which the oil yielded at firft, it is another certain proof, that it is mixed with fome cheaper effential oil. But as it cannot be known before-hand, what oil is mixed with it, the trial ought to be made according to all thefe methods. A genuine effential oil muft be perfectly foluble in fpirit of wine, not make the water turbid nor milky, nor emit any fmell during its evaporation different from that of the fubftance from which it was extracted.

However carefully thefe oils are kept, they will yet, in length of time, become infpiffated, and lofe fomewhat of their original flavour. The beft method, when there is enough of it to make it worth while, will be to diftil the oil afrefh in a retort, with a fufficient quantity of water. The deftruction here fpoken of proceeds from the lofs of part of its volatile etherial matter, which takes place gradually; confequently, part of thefe infpiffated oils ftill retains its original compofition, though at the fame time another proportion may be decompofed by the

the eſcape of the ſpirituous part; conſequently it is only this entire and undecompoſed part which will be ſeparated by diſtillation, and freed from the reſinous part. It is commonly in this ſtate alſo of the oils, that the peculiar volatile oily ſalts are ſeparated, which have been deſcribed before, at page 321.

When an inſpiſſation of this kind has already taken place in them naturally, before they were ſeparated from the ſubſtance that contained them, they appear in quite a different form, being either of a thick conſiſtence or hard, and then are called either *balſam*, or *reſins*. The different native balſams have, even in their natural ſtate, the perfect external appearance of inſpiſſated eſſential oils, and alſo reſemble them in their compoſition. Like theſe, they exhibit a tolerably free and diſengaged acid; an eſſential oil may be diſtilled from them, and a reſinous part is left behind, as in the former*. The balſam of copaiba yields an etherial oil and leaves a reſin behind; and the caſe is the ſame with turpentine, after the diſtillation of which there remains what is called boiled turpentine, or *Burgundy pitch*; whence, by farther coction and evaporation of all the watery and oily parts is prepared *colophony*, or common reſin. The reſins of the ſilver and red fir-trees, from which an etherial oil and pitch are obtained, are proofs of this aſſertion. Natural balſams, ſuch as theſe, ſhould conſequently be conſidered as inſpiſſated etherial oils, as indeed theſe alſo are nothing more than liquid reſins. Camphire may, among others, likewiſe be conſidered as an inſpiſſated ethereo-oleaginous ſubſtance of this kind, which, like other balſams and reſins exudes from the camphire tree in a concrete ſtate, and inſtead of being procured by eliquation, like the preceding, requires to be ſeparated from the woody parts by ſublimation. It exhibits a dry cryſtalline etherial oil of a peculiar kind, or rather a *peculiar and totally volatile etherial reſin*. It is, like theſe oils and reſins, equally difficult of ſolution in water, and diſſolves as readily as theſe do in ſpirit of wine; it is, like them, extremely inflammable, and burns

* M. *Berthollet* has ſhewn in the *Mem. de l'Acad. des Sciences*, 1785, that it is not by any decompoſition, but by abſorption of air from the atmoſphere, that theſe oils become inſpiſſated; and that reſins differ from eſſential oils only as they contain more air. Diſtillation then ſeparates the more volatile part, and leaves the groſſeſt particles behind, in union with all the air that the oil had before abſorbed, and which appears now to ſubſiſt in it in the form of an acid, which has been generated by its union with the vegetable principle of the oil. This groſſer part therefore, in all probability, conſiſts chiefly of the vegetable principle, which now united with air, and a proportionately ſmall quantity of inflammable gas, forms a reſin. [E.]

away intirely without leaving a coal behind it. By ſmoking nitrous acid, and vitriolic air, camphire is brought into a liquid oily ſtate; but by the addition of water it is made to reſume its natural concrete form.

With reſpect to *reſins*, it may be proved, that they have an etherial oil for their baſis, which however has been reduced to a concrete ſtate by a redundancy of acid; this may be inferred from the conſideration of the phenomena preſented by nature, as well as of the appearances exhibited by art. From all natural reſins, an etherial oil and an acid may be produced; and the artificial compoſition of a reſin is an additional confirmation of this poſition. In the firſt place, a reſin thus compounded may be extracted from the reſiduum of vitriolic æther, which is produced from the etherial oil of ſpirit of wine and the vitriolic acid; ſecondly, it is produced, when an etherial oil is mixed with oil of vitriol, and kept in digeſtion for ſome time. But the moſt remarkable and cleareſt proof is exhibited by the preparation of a peculiar reſin, deſcribed by M. *Marggraf*, by which, not only an etherial oil is almoſt immediately converted into a reſin, but alſo there ariſes at the ſame time from the former a very balſamic ſmell, like that of muſk. Firſt, one drachm of well-rectified oil of amber is to be poured into a beer-glaſs, to which is to be added gradually, in ſmall portions, two or three drachms, (according to its ſtrength) of ſmoking ſpirit of nitre. The inſtant the addition is made, a denſe browniſh-red vapour will ariſe, which has a ſmell of muſk, and no ſooner is the mixture made than the reſin is formed: it is better however to let the glaſs ſtand till the next day. The reſin may now be taken out and waſhed with water till it has loſt all its acrimony. It is of an orange-colour, ſmells ſtrongly of muſk, and diſſolves copiouſly in alcohol, with which being mixed, it produces a *balſamic tincture of amber*, (tinctura ſuccini balſamica) of great efficacy and power.

All reſins, on account of the ſimilarity of their nature with that of eſſential oils, require alſo ſpirit of wine for their complete ſolution, excepting that ſome of them, on account of their poſſeſſing a larger portion of acid, are diſſolved with greater difficulty. Upon this is founded the artificial extraction of reſins in ſmall quantities. The ſubſtances containing them are to be well dried, reduced to a coarſe powder, and their ſoluble parts extracted with a ſufficient quantity of ſpirit of wine by a gentle heat. This tincture, being purified from all feculent matter, is then to be mixed with a fourth part of water, and diſtilled till the whole of the ſpirit is drawn over. In this operation the reſin extracted remains in the diſtil-

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ling veſſel, without mixing with the water, that has taken up the gummy part only, from which the former may now be ſeparated, and, according to the views of the operator, be farther evaporated to the requiſite conſiſtence over a gentle fire. In this manner, the *reſin* is obtained from the roots of *jalap*, from *ſcammony*, *guiaiacum* wood, and many other vegetable ſubſtances. When the reſinous part, in its natural ſtate combined with a great many mucilaginous, gummy and alkalino-ſaline particles, is miſcible with water, it may even ſometimes be ſeparated by an acid from an aqueous decoction of any of theſe ſubſtances, as I have experienced with reſpect to the decoction of *arnica*. The extraction of *gum-reſins* is made either with beer, wine, or aqueous ſpirit of wine; in this caſe however the extracted parts muſt be evaporated together. Of this latter kind appears to be the *elaſtic reſin*, which is obtained in its natural ſtate of compoſition, by the ſpontaneous evaporation of the reſinous juice of the *Caoutchouc-tree*. Hitherto it has been found to be beſt diſſolved by vitriolic æther, oil of roſemary, nitrous acid, oil of vitriol, and fixed alkali. *Hoffmann*'s anodyne liquor and alcohol have been obſerved to act leſs powerfully upon it. Natural reſins manifeſt themſelves either ſpontaneouſly on the ſurface of the ſtem or ſtalk in the vegetables that contain them, or elſe they are made to iſſue forth more copiouſly by inciſion, and afterwards collected.

The ſecond kind of oily ſubſtances are called *unctuous* or *fat* oils, becauſe they are fat and unctuous to the touch. Theſe are inſoluble in ſpirit of wine, and in diſtillation with water do not riſe over the helm. They contain in their compoſition more water, more acid, and more mucilaginous and earthy parts, but leſs pure matter of fire than the eſſential oils, and finally, are either of a *liquid* or *ſolid* nature.

The *liquid fat* oils are chiefly obtained by expreſſion, and hence are called *expreſſed* oils. They are moſt commonly met with in, and are to be obtained from, ſeeds and kernels of various ſorts, ſuch as rape- flax- hemp- poppy- tobacco- oil-radiſh-* and ſun-flower-ſeeds; not to mention olives, almonds, walnuts, haſelnuts, beech-maſt, horſe-cheſnuts, &c. † After being previouſly bruiſed or ground ſmall, they are gently heated, and the oil preſſed out from them in ſmall quantities. They may be extracted alſo by decoction, though with leſs advantage. In pharmacy, by decoction with various bodies, they are impregnated with fo-

* Or Raphanus Chinenſis annuus oleiferus, a variety of the common radiſh. [E]

† The kernels of grapes too have been lately found to yield an oil of this kind in abundance. [E]

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foreign ſubſtances, with a medical view, and for the ſake of adding to their efficacy. In the animal kingdom, ants and the yolks of eggs, yield an oil of this kind. In order to procure it from theſe latter, they muſt be boiled hard, and cleared of the whites; they are then to be evaporated by a gentle heat, till all their moiſture is diſſipated, and the oil is to be preſſed out of them, while they are yet hot. The fat oil of ants is found ſwimming upon the ſurface of the reſiduum (on preſſing it) which remains after the diſtillation of the acid. Very ſimilar in its nature to theſe oils is *Train-oil*, which is melted out from the fat of whales, ſeals, ſea-bears, ſea-horſes, herrings, &c.

The former of theſe expreſſed oils are diſtinguiſhable from each other, not only by their ſmell and taſte, but alſo by the circumſtance that ſome are coagulated by cold and others not; and again, that ſome dry in the air, and become ſolid, but others, on the contrary, remain always greaſy. Between the animal oils there is little difference to be obſerved; but they differ exceedingly from the vegetable oils; it is probable therefore that their compoſition is more diverſified*. But in this reſpect they all agree, that by length of time, and eſpecially in a warm ſituation, they acquire an offenſive ſmell, and become rancid and acrid. As far as the cauſe of this corruption has hitherto been traced, it is in all probability owing to the acido-mucilaginous particles, which in the expreſſion of theſe oils ſtill remain united to them, and generally alſo communicate to them a proportionably dark tinge, they being naturally limpid and colourleſs. Theſe particles are very ſubject to corruption; and when they are actually in this ſtate, occaſion the offenſive rancid ſmell and taſte perceivable in the oils. For preventing this inconvenience, Profeſſor *Oettinger's* advice, to deprive ſuch bodies, as are to be expreſſed, of their peels or huſks, and then to preſs out the oil without the application of heat, is incontrovertibly the beſt. It is very true, this practice can be applied to large kernels only, ſuch as almonds, &c. But with other ſmaller ſeeds, if it be intended to preſerve them from theſe defects, the ſeparation of theſe heterogeneous corruptible parts

* Animal oils, according to M. *Berthollet*, Mem. de l'Acad, des Sc. 1786, contain mephitis, in conſequence of which they yield volatile alkali in diſtillation. But vegetable oils give out an acid only in their decompoſition. This may be true, with reſpect to mere diſtillation: but there muſt neceſſarily be a ſmall quantity at leaſt of mephitis in vegetable oils, ſince they, as well as the vegetables from which they are extracted, yield volatile alkali by putrefaction, though by no means ſo copiouſly as animal oils and ſubſtances. The difference then between theſe two kinds of oil conſiſts, perhaps, merely in the different proportions of the mephitis contained in them. [E]

ought to be attempted immediately after the expreſſion; for when oils are once become rancid, it is no longer in the power of art to remove the bad quality. Now, for this purpoſe, Dr. *Struve*'s advice might be eaſily put into practice for large quantities, which in an experiment he made in ſmall, was attended with the deſired ſucceſs. He filled the fourth part of a bottle with clean waſhed ſand, and the reſt with three parts of boiling water, and one of linſeed- or olive-oil. Having ſtopped the bottle cloſe, he ſhook it frequently and for a long time together; and as often as the water appeared to be turbid, he poured it off, and added freſh water; and this was repeated till the water remained clear. In this manner he rendered both the linſeed and olive-oil quite colourleſs, which did not exhibit any ſigns of rancidity, for a long time after. This proceſs is ſimple, cheap, and perfectly adequate to the purpoſe. The mucilaginous parts are ſeparated by the water; while the ſand, by means of the agitation, promotes the penetration of the water into the interſtices of the oil.

When ſimilar fat oils of the vegetable and animal kingdoms are united with a large portion of acid, they acquire a greater degree of ſolidity, as may be proved by barely mixing the fat oils with different acids, and alſo by the chemical analyſis of theſe denſe fats. Of this ſort, in the vegetable kingdom, are the following, viz. *butter* of *cocoa*, expreſſed *oil of mace*, common *bees-wax**, the *wax* which is obtained by a decoction of the fruit of the wax-tree, and the *tallow* which is obtained in like manner from the fruit of the tallow-tree. Of this ſort, in the animal kingdom, are butter, lard, tallow †, and ſpermaceti.

The *empyreumatic oils* form the third claſs of oils; they are diſtinguiſhed by a diſagreeable empyreumatic ſmell, a browniſh-red or black colour, and a pungent taſte. They are extracted from vegetable and animal ſubſtances, or their parts, by the ſole action of fire, without the addition of any other fluid. They are, in fact, nothing elſe than the above-deſcribed different oils and fat bodies; but which, having ſuffered the action of the fire, and thus been converted into vapour and altered, are by this means become empyreumatic. Hence, ſuch bodies only

* M. *Berthollet* ſuſpects wax to be an expreſſed oil, united with pure air, and has made ſome approaches towards imitating this ſubſtance, by expoſing a very thin ſtratum of oil of ſweet almonds diffuſed upon water for above three months to the air of the atmoſphere. Vid. Mem. de l'Acad. l. c. [E]

† The fat, diffuſed throughout the cellular membrane of animals, yields an acid in diſtillation; for which reaſon it is to be conſidered as poſſeſſing the properties of vegetables. *Berthollet*, l. c. [E]

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can yield these oils, as contain oily, gummy, mucilaginous or resinous component particles. The more there is of these, the greater the quantity of the oil which is obtained, and where they are not, no such oil is produced; because it is impossible for art to form a single drop of oil where there is none already present. Consequently these oils are derived in all cases from the oily and fat substances, in the composition of the bodies, and in so far they must be considered as the oily component parts of bodies disengaged and separated. But when we attend to their present colour, smell and taste, which they had not before, and which the sole action of fire occasioned in them, they may in respect to this alteration of their properties, be considered as newly generated bodies, because the oily matters in their composition did not possess the same properties before distillation.

Now, as the composition of the above-mentioned natural fats is found to be different, so there is also a great difference perceptible among the empyreumatic oils which are obtained from them, with regard to smell, colour, taste, substance, and to their composition in general. Of this we have instances in the tar used for greasing cart-wheels, in the oil of wax, in the oleum lateritium, in the oils of soap, hartshorn, amber, and pit-coal.

*Tar* is, properly speaking, nothing more than an empyreumatic oil, which is still mixed with half-decomposed resinous and gummy particles *. It is prepared from the wood of the Scotch and silver firs, in furnaces constructed for the purpose †. One of these furnaces is filled with logs, or roots of the Scotch fir,

* Tar and pitch, according to *Berthollet* and *Lavoisier*, consist of undecomposed ethereal oil mixed with particles of charcoal, which causes their dark colour. Here it is evident that we must take the word *charcoal* in the *mystic* sense, in which it is commonly used by these ingenious innovators (and by which they mean nothing more than what we have designed under the name of the vegetable principle) but real substantial charcoal, which by its blackness gives a dark tinge to the oils with which it is united: for, as for the other charcoal, they do not seem to know whether it be black, blue, or yellow. In fact, the *sulphur* of the antient chemists, from the confusion of which we were delivered by the now almost obsolete *phlogiston* of *Stahl* was but a type of M. *Lavoisier's* charcoal. But "Humanum est errare," is a sufficient excuse for a philosopher in every other instance remarkable for the clearness of his ideas. [E]

† Tar-furnaces do not appear to have been known so early as in the times of *Theophrastus Eresius*; inasmuch as in the description of the extraction of pitch by fusion, he only mentions, that the heaps of wood that were piled up, were covered with earth. Vid. hujus *Historia Plantarum*, Lib. IX, Cap. III. On the other hand, *Dioscorides*, at the early period in which he wrote, gives a description of them. [A]

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which abound in resin; it is quite closed up with brick work, and heated on the outside; in which operation therefore, by means of a distillation, per descensum, that ensues, a kind of eliquation takes place, and by a channel contrived in the lower part of the furnace, is obtained: 1. A pure attenuated resin: 2. an empyreumatic acid phlegm: 3. tar of a hue more or less dark. Coomb or *cart-grease* may be composed by art in the following manner, and made to imitate the natural tar. Let twelve pounds of shoemaker's pitch or wax, as it is called, be melted over a gentle fire; to this let there be added an equal quantity of soap-lees, and the mixture stirred well till it becomes thick; according as it is more or less thick, a quantity of linseed-oil is to be put to it, till it becomes of the proper consistence. The sediments of linseed- rape- or train-oil, may also be used for this purpose.

For making *Oil of Wax*, the wax is melted over the fire, and about an equal quantity of dry sand, by measure, is to be mixed with it. When it is cool, a coated glass or stone-ware retort is to be properly filled with it, and all the oily parts distilled over by an open fire, which however in the beginning ought to be very gentle. The sand is added merely to prevent the wax from boiling over.

The *Oil of Bricks* (Ol. Lateritium, Ol. Philosophorum) is one of the most ancient oils of this kind, which is even described by the Arabian *Albukases*, who is said to have lived in the eleventh century. It has obtained its name from this circumstance, that at first hot bricks were steeped in oil of olives, and then subjected to distillation. In our times, balls are made of this oil and brick-dust, or rather lime slaked in the air; a stone-ware retort is filled with them, and the whole carefully drawn over from it by an open fire. Instead of olive oil, rape- or linseed-oil may be used without scruple for this purpose.

From this *Oil of Soap* does not differ greatly. For this purpose the soap is cut into thin slices or shavings, mixed with an equal quantity of sand or lime slaked in the air, and distilled in a retort, like the two preceding substances. The same process will answer for butter, lard and tallow, as for wax; and an oil will be obtained not very different from oil of soap.

*Oil of Hartshorn* is obtained adventitiously, when hartshorn is distilled for the sake of the volatile spirit or salt. This oil is not different from that, which by a similar treatment is obtained from any other horns, or from the bones, hair, blood, silk, or other parts of animals.

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In order to obtain *Oil of Amber*, a ſtone-ware retort muſt be filled only one third, or half at the moſt, with pieces of amber, with which may be mixed any quantity of ſand ad libitum. The retort being properly placed in a reverberatory furnace, the diſtillation is carried on with a very ſlow fire, ſo that the receiver may be always but barely warm, till at length, on increaſing the fire, no increaſe of heat is perceived in the receiver. By this diſtillation, beſides the oil, an acidulous phlegm will be found to have paſſed over, which contains the volatile ſalt *.

*Pit-coal Oil* is diſtilled in ſmall quantities, in ſtone-ware retorts, with an open fire. But in large quantities, it is drawn over with more advantage in furnaces which reſemble thoſe uſed in making tar. By this latter method, according to M. *de Pfeiffer's* aſſertion, ſix hundred weight of good pit-coal yields eight hundred ale quarts of a ſtyptic water, fifty of acid ſpirits and two hundred of oil.

It is a very remarkable circumſtance in all empyreumatic oils, that by rectification they actually acquire all the properties of etherial oils. No expreſſed oils, lard or ſuet, riſe in diſtillation with water: but of the empyreumatic oils obtained from theſe a conſiderable portion will be forced over with the water, which ſhews that they have acquired a higher degree of volatility. Beſides this, they are alſo become ſoluble in ſpirit of wine, which was not the caſe before. Fat bodies likewiſe undergo the ſame change, after having been made into ſoap with a cauſtic lixivium only, and then ſeparated from this by means of acids. In both caſes the natural compoſition of the oils is undoubtedly in ſome meaſure deſtroyed, part of the water and acid is ſeparated, and more of the matter of fire united with them; by which they muſt neceſſarily acquire a greater degree of volatility and ſolubility. Upon this very circumſtance is founded the preparation of *Dippel's Oleum Animale* (Ol. Animale Dippelii). The inventor, whoſe name it ſtill bears, at firſt prepared it of the empyreumatic oil of ſtag's blood; but as it has been diſcovered, that there is no ſpecific virtue in this blood, and that all the ſolid parts of animals yield one and the ſame empyreumatic oil, it

* Four pounds of amber properly diſtilled, will yield about an ounce of fine white concrete ſalt; and the acid liquor that comes over will produce, by a very ſlow evaporation, about two drachms of ſalt: but as much of the ſalt is diſſipated during the evaporation, it is adviſable, where the liquor cornu cervi ſuccinatus is uſed, to ſaturate the liquor with ſalt of hartſhorn. *Dollfuſs*, Pharmaceutiſch-Chemiſche Erfahrungen. [E]

has been uſual for a long time back to employ the oil of hartſhorn for this purpoſe. Others, who are not afraid of its lying heavy on their conſciences, and do not wiſh to be the inſtruments of raiſing the price of hartſhorn to the cutlers, employ indiſcriminately all the ſolid parts of animals, as the bones and horns o any animals whatever. Now in the preparation of Dippel's oil from the empyreumatic oil obtained by the firſt diſtillation, the main point conſiſts in the ſeparation of the extremely ſubtle etherial oil contained in it. This is beſt obtained, and without much trouble of rectification, by adding to a quantity ad libitum of oil of hartſhorn, or of any other oil of this kind, a rather low matras, a quantity of ſifted aſhes, and after ſetting on the head, diſtilling as much of it with the requiſite degree of heat in a ſand-bath, till the oil that comes over begins to grow thick. The oil thus diſtilled, is after this poured with the addition of an equal quantity of water into a freſh matras, covered with another head, and rectified again in a ſand-heat, till the oil that paſſes over begins to be coloured. In this manner a colourleſs, and not very diſagreeable etherial oil, ſoluble in ſpirit of wine, will be obtained, and that even in the ſecond diſtillation.

Similar kinds of empyreumatic oils are alſo to be found in nature, known by the name of *Petroleum, Stone- or Rock-Oil* (Oleum Petræ), and diſtinguiſhed from each other by different degrees of fineneſs and volatility. The fineſt ſort is ſimply called *Naphtha*; it is very volatile, inflammable, and not diſagreeable to the ſmell, without colour, and ſoluble in ſpirit of wine; the inferior ſorts are of a higher colour, thicker, of ſomewhat more diſagreeable odour, and are ſimply called *Petroleum*, or *Rock Oil*. The ſorts which are of a ſtill greater conſiſtence, and a higher colour, bear the name of *Mineral-* or *Rock-Tar*. It is highly probable, that all theſe ſubſtances are propelled with water from the different kinds of pit-coal in the interior part of our globe to its ſurface, by ſubterranean heat.

Now, as on the ſurface of the earth the more ſubſtantial balſams and hard reſins belonging to the vegetable kingdom are acknowledged to have an etherial oil for their baſis; ſo the caſe is the ſame with the bituminous ſubſtances under the earth, ſuch as *mineral tallow, mineral balſam, aſphaltum, amber* and *ambergriſe*. But theſe ſeem in like manner to have their baſes in the different oils beforementioned, and their more inſpiſſated nature from a portion of acid, which alſo may be the reaſon of their difficult ſolubility in ſpirit of wine. Of the three latter, the ſtrongeſt alcohol diſſolves a ſmall part only, which ſeems to be of a mere

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vegetable and resinous nature; the greatest part however remains quite undissolved, unless recourse be had to the assistance of other substances.

Of the different combustible bodies of the mineral kingdom, *fossil-* or *pit-coals* probably constitute the greatest part, of which the great excellence consists in the large proportion of inflammable oleaginous particles subsisting in their composition. In their use, frequent complaints are made of an actually sulphureous smell, or of some other offensive and empyreumatic stench, as well as of the solid earthy slag they leave behind. But these and similar defects, may be easily removed, according to M. *de Pfeiffer*, by a tolerable chemical knowledge of their causes, when their constituent parts are previously known. Now, these are generally a ferruginous argillaceous earth, the marine and vitriolic acids, volatile alkali with a great many bituminous particles, and, sometimes besides intermixed with pyrites. The means of remedying such defects, are briefly these: that the vitriolic acid be extracted from these substances; and that they be freed from the oil contained in them. By this means they will better, give a greater heat, and be less offensive to the smell, and the earth remaining will be less troublesome. All this is effected by charring them, or setting them on fire in large close vessels constructed for the purpose. *Jet* is a more solid compact kind of pit-coal, and more abounding in bituminous particles; while *Earth-coals*, on the other hand, are a coarser, more spongy, and meagre sort of common fossil coal. In *Slate-coals* the basis is generally of an argillaceous nature, but the proportion of the inflammable part smaller, whence they are much less fit for maintaining fire. In other lapideous substances of a similar nature, the quantity of this inflammable part is still less, and indeed in these it manifests itself only by a dark colour, which however vanishes again when the substance is exposed to a red heat. In like manner too, the various combustible earths, from the *bituminous earths* down to *umber*, considered chiefly as fuel, are discriminated from each other by the quantity of bitumen contained in them.

Of the same nature alo are the different sorts of *peat* or *turf*, which, in the same manner as the *bituminous woods*, abound in oleaginous particles, and, according to the proportion of these particles, yield more or less heat. What has been said on the subject of the improvement of pit-coals, may also be applied to the solid sorts of peat: by igniting them without the free access of air, certain inconveniencies and defects in them may be removed. It is beyond all contradiction, that peat consists of marshy vegetables, whose roots are intermixed with a kind

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of bog- or moorish-earth, and afterwards compose one entire body with it. The excellence of it depends on the quantity of oleaginous particless contained in it, with which its bog-earth is replete. The origin of these oleaginous particles it is not difficult to discover. It appears probable, that the oil of the different kinds of peat, is the oil or resin of mouldered vegetables, which is altered by putrefaction*. When peat after combustion leaves brown ashes behind it, it is a sign that it contained earth of iron, and as this earth also very frequently contains vitriolic acid, it will be generally found that this kind of peat yields a more sulphureous smell than others.

Various opinions have been entertained respecting the origin of bituminous substances in the earth, both of those that are pure, and also of those which are intimately mixed with earth; since philosophers could never be convinced that they belonged originally to the earth. These bodies, it is true, cannot exhibit a certificate of their birth-place; nevertheless they are not absolutely without a pedigree. How often do we meet with whole trees converted into fossil coal, in such quantities together, as to exhibit entire forests; in which the roots, trunk, branches, bark, the trees age, and even the difference of the wood are discernible? There are specimens known of fossil coal, that still consist half of real wood unaltered; and of others again, which consist of petrified wood on both sides, and pit-coal in the middle. Impressions of leaves have been found inclosing the leaf itself, the parenchyma of which was converted into pit-coal, and this even in sand-stones. The numerous impressions of herbs in common coal-pits and slate-quarries; the ordinary situation of fossil-coal in strata or beds, and many more arguments which are to be met with in the work above-mentioned, render it very probable, that the phlogistic contents of pit-coal and peat, are originally derived from the vegetable kingdom, of which incredible quantities have been buried in the earth in the different great revolutions of our globe, and which, by the putrefaction they have sustained, and by the action of saline particles, must have been considerably altered. With respect to naphtha and the other species of Petroleum, it is more than probable that they are derived from strata of fossil-coal that have been burned; and that these bitumens have arisen from the gradual inspissation of the former, is no less probable, since our senses themselves afford the

* The most convincing arguments on this subject are to be found in "Observations, Doubts, and Queries, with respect to Mineralogy. Essay I, Hanover, 1778. [A]

moſt palpable proofs, that they muſt have formerly been in a liquid ſtate. In addition to all this may be adduced the effects of art upon various vegetable oils by the means of mineral acids, ſo as to imitate the natural bitumens; and indeed, with reſpect to its balſamic flavour (vid. page 527) the artificial reſin prepared from oil of amber, deſerves in ſome meaſure to be compared with theſe ſubſtances.

The principal oleaginous bodies having now been deſcribed, a few particulars remain to be mentioned relative to the application of them to different uſeful purpoſes. The liquid ſorts may be employed as ſolvents for the more ſolid fat and reſinous bodies, by which various kinds of varniſhes are produced, which will be treated of in the next chapter. From the combination of eſſential as well as expreſſed oils with the different calces of lead, are obtained the various kinds of *ſaturnine ointments*, *ſalves* and *plaſters*. The coſtly eſſential oils are chiefly employed for medical purpoſes; the unctuous oils, beſides the uſe that is made of them to light up our ſtreets and apartments, are alſo uſed for ſoap, and for imparting pliability to different ſubſtances. The coarſer ſorts of petroleum may be uſed partly for burning, and partly for healing wounds in cattle, or for coomb to greaſe the wheels of carriages with.

As an inſtance of the uſes to which ſolid reſinous bodies may be applied, I ſhall only mention the preparation of *ſealing wax*. Hitherto, the reſin called *Lac*, ſeems to be the only ſubſtance that poſſeſſes every requiſite for this purpoſe. It therefore conſtitutes the principal ingredient and indeed the baſis of the commodity here ſpoken of; its great hardneſs and brittleneſs is diminiſhed by the addition of a ſmall quantity of turpentine, and its diſagreeable brown colour concealed by the addition of vermilion, which, however, when the colour is intended to be bright, and to remain ſo, muſt by no means be adulterated with red lead, and ought to be levigated as fine as poſſible. In order to prevent the colour from being ſpoiled, the turpentine muſt be previouſly boiled a little, by way of depriving it of part of its etherial oil, which otherwiſe yields too much ſoot when ſet on fire: farther, the cleareſt gum lac muſt be ſelected for this purpoſe, and, together with the inſpiſſated turpentine, be melted by a gentle heat. When this is done, the veſſel muſt be taken from off the fire, and finally, the vermilion mixed and ſtirred up with it for a very conſiderable time. For inferior ſorts, a proportionable quantity of common reſin is added beſides. For making *blue ſealing-wax*, the gum lac muſt be deprived of its colouring contents by boiling in water, with the addition of ſome alum, and coloured with fine Berlin blue. But this ſort is not capable of being ſet on

fire,

fire, nor uſed in any place but where it can be melted over burning coals. The caſe is the ſame with the *green ſort*, which is prepared with verdigriſe. In the *black* ſealing wax, the ſubſtance that forms the baſis is coloured with lamp-black, for which purpoſe alſo the pure and ſolid kinds of bitumen may be employed. In order to give an agreeable ſmell to any of theſe different ſorts, a ſmall quantity of reſin of benzoe, reduced to a fine powder, may be melted with it. The forming of theſe articles into ſticks depends entirely upon manual dexterity.

In the deſtruction of inflammable bodies by fire, two objects beſides preſent themſelves, among others, to our notice, which deſerve to be mentioned here; viz. *ſoot* and *coals*. Both theſe ſtill continue to be inflammable ſubſtances, but differ from each other in their compoſition.

*Soot* is diviſible into two kinds; common *wood-ſoot*, and *lamp-black*. Both may properly be conſidered as coals volatilized; but the circumſtance by which they are diſtinguiſhed, as well from each other as from common coals, will immediately appear from a more accurate deſcription of theſe ſubſtances. In the combuſtion of wood there are conſtantly detached at the ſame time with the aqueous parts, a portion of lignic acid, half burned oil, volatile alkali, and ſome attenuated earthy particles, which have withdrawn themſelves from the deſtructive action of the fire, before it could exert its influence upon them. The aggregate of all theſe particles conſtitutes the viſible ſmoke of fire that paſſes into the chimnies, to which the more fixed particles attach themſelves, and form *chimney or wood-ſoot*; while the aqueous parts mount aloft, and are diſperſed in the air. The component parts of ſoot conſequently are a vegetable ammoniacal ſalt, a half-burned oil and earth. But the reaſon why ſoot nevertheleſs, by ſimple diſtillation, yields nothing but volatile alkali, and an empyreumatic oil, leaving the earth behind, will eaſily be conceived, if we call to mind, that ſoot contains a vegetable acid, and that this is not of a fixed nature, and in the preſent inſtance is conſumed by fire. Of a very different nature is *lamp-black* or *pine-ſoot*; this contains no perceptible ſaline conſtituent parts at all, and conſiſts merely of an extremely ſubtle phlogiſticated earth, which is produced when the flame is not to able to deſtroy or decompoſe completely all the oleaginous materials that are ſoluble by fire; for this reaſon, a ſtill, moderate flame from oil yields no ſoot; but if the point of the flame, where the ultimate decompoſition takes place, be divided, ſoot is inſtantly produced. It is prepared in the great, in furnaces of a particular conſtruction, by burning in them the grouts that remain after the eliquation of pitch, or elſe fir-tree wood in ſmall portions,

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the ſmoke of which is made to paſs through a long horizontal flue, that terminates in a very cloſe boarded chamber. The roof of this chamber is made of coarſe linen or woollen cloth, through the pores of which the air eſcapes, and leaves the ſoot behind. Now ſince theſe different ſorts of ſoot are half deſtroyed combuſtible reſidua, and likewiſe reſemble coals in their colour, they may juſtly be conſidered as carbonaceous ſubſtances of a peculiar kind.

All ſubſtances that bear the name Charcoal, have the property of not being decompoſible, even by the moſt violent fire, in cloſe veſſels, to which air has not free acceſs; neither can putrefaction, which deſtroys every thing, exert its power upon them. But as ſoon as they are ſet on fire, and the open air has acceſs to them, the air, which they ſtill contain, eſcapes, together with the phlogiſton, and a ſmall portion of acid, in the form of phlogiſticated * or inflammable

* Phlogiſticated air, more properly termed mephitric gas, is produced in the combuſtion of ſubſtances containing mephitis, ſuch are all animal ſubſtances, and ſome vegetable, particularly the cruciform, or antiſcorbutic plants, which compoſe the claſs of Tetradynamia in *Linnæus*'s Syſtem. As to real air, there is none known to exiſt in vegetable or animal ſubſtances, excepting in ſo far as it conſtitutes part of the acid that enters into their compoſition; the aëriform fluids that are extricated from them by combination as well as fermentation, conſiſting either of inflammable gas, or aerial acid (improperly called fixed air) and in ſome caſes of mephitic gas. The portion of this latter gas that is conſtantly found in the receiver under which any organic ſubſtance is burned, being now generally attributed to the decompoſition of the common air, or atmoſpheric fluid ſurrounding them, which *Scheele*, in his excellent *Treatiſe on Air and Fire*, has ſhewn to conſiſt of mephitis and pure air. But if plants in general do not contain mephitis, whence comes the volatile alkali, mentioned juſt above, as exiſting in wood-ſoot?

Upon the whole, charcoal appears, from the experiments of *Lavoiſier* and *Bertbollet*, to be an oil deprived of its inflammable gas. But coal of wood (or common charcoal) likewiſe contains fixed alkali, which ſoot (or the coal of oil) does not; but inſtead of this, exhibits volatile alkali. The fixed alkali of the former proceeds from the plant itſelf, and this, in the caſe of ſoot, is joined with inflammable gas, and forms volatile alkali, the earthy part being left behind; as happens when this latter is prepared from fixed alkali. Genuine charcoal therefore conſiſts of this vegetable principle, united with a little alkali, and part of the phlogiſton that conſtituted the oil of the plant of which it is made: for ſome of this principle is carried off, together with the hydrophloge, in the form of inflammable gas, if diſtilled in cloſe veſſels; but, if burned in the open air, the hydrophloge unites with the pure part of the air, and forms water. From theſe conſiderations as well as from the experiments and obſervations of M. *Berthollet*, in the Mem. de l'Acad. des Sc. pour 1786, p. 33, et ſeq. it appears that common Charcoal conſiſts of the vegetable principle, ſome phlogiſton, fixed alkali, and no inflammable gas: (ſoot containing volatile alkali, is conſequently poſſeſſed of ſome ſmall portion of this gas) Oils of an equal quantity of the vegetable principle, more phlogiſton, and a certain portion of inflammable gas, Æthers and Ardent ſpirit of a ſtill greater quantity of this gas. [E]

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mable air, and leaves the earth behind, with the fixed ſaline particles (if there be any preſent) in the ſame manner as takes place in vegetable coals. This is the only ſure way of perfectly ſeparating the component parts of charcoal. It is true, *Beaumé* mentions yet another method of decompoſing them, viâ humidâ, by oil of vitriol; but in the very deſcription he gives of it I find great reaſon to doubt that the requiſite precautions were attended to in the proceſs.

The eſſence of every kind of *charring*, conſiſts in the ſeparation of the air, and of the aqueous, volatile ſaline, and oleaginous particles of inflammable bodies in cloſe veſſels, whether this be accompliſhed with or without inflammation. In this latter manner inflammable ſubſtances are charred in the diſtillation or combuſtion of them, in cloſely cemented crucibles, and in the ſame manner the *teſt of charcoal* is made. The charring of wood in the great is done in piles, which are diſtinguiſhed by the different appellations of *upright* and *horizontal piles*. In the former, on the ſpot where the pile is made, the billets of wood are placed upright, round one or more poſts, upon and over each other in different layers; and underneath a hole is left for lighting up the pile. The whole pile is then covered with turf, moſs, and at laſt with earth, and ſet on fire at the bottom. They endeavour to regulate the fire in the ſmoking pile, by gradually covering this latter with earth, and ſometimes alſo by making an opening in it, according to the difference of circumſtances, in ſuch a manner, that the whole may burn thoroughly, and the watery ſmoke only eſcape. This external coating performs the ſame office here that a cloſe diſtilling veſſel does in ſmall quantities; hence an acid juice of wood runs out from the lower part of the piles, which is in every reſpect ſimilar to the fluid found in the receiver. In the *horizontal piles* the billets are laid in parallel lines by the ſide of each other, ſo that the charcoal-place is made ſquare. The beſt kind of charcoal is heavy, ſolid and ſonorous, and neither ſmokes nor crackles in the fire: the inferior charcoal is that which has been over-burned, or elſe burned and afterwards extinguiſhed, which for this reaſon is called *quenched charcoal*. Charcoal is alſo diſcriminated according to the different kind of wood which have been employed in making it. The ſmall duſty coal may be mixed with a little thin loam, and formed into large balls. It is remarkable that the charring of wood was known in the times of *Theophraſtus Ereſius*, juſt as it is now. The charring of pit-coal and peat has already been mentioned before *.

Finally,

* Lord *Dundonald*'s excellent method of making Coak muſt not be paſſed over in ſilence. By a peculiar diſtilling apparatus he collects the different products of the coal: the oil is employed inſtead

Finally, in the clafs of inflammable bodies, the *fulphureous* remain to be treated of, by which denomination are underftood fuch bodies as are compofed of an acid and phlogifton. Among thefe, common fulphur juftly claims the chief place, which confifts of the vitriolic acid and phlogifton, intimately united with each other, and from which the others, on account of the fimilarity of their compofition, take their generic name. With refpect to the real proportion of the two conftituent parts of fulphur, concerning which our anceftors had very extrordinary ideas, it has been determined with certainty, by Mr. *Kirwan*, that 100 parts of fulphur confift of 59 $\frac{39}{100}$ parts of acid, and of 40 $\frac{61}{100}$ of phlogifton, or, in round numbers, of $\frac{3}{5}$ of vitriolic acid, and $\frac{2}{5}$ of phlogifton. This proportion certainly at leaft approaches the neareft to the truth †.

Nature itfelf yields it in great quantities, partly in a pure ftate, partly in fubftances called pyrites, in various metallic ores, and many other combinations befides. From thefe it is extracted and obtained by art, either purpofely or adventitioufly. The former is done in fmall quantities, by putting the pyrites into a ftone-ware retort, and forcing the fulphur over by an intenfe fire, on which occafion the fulphur paffes into a receiver half filled with water; part alfo attaches itfelf to the neck of the retort. In the great, this feparation is made in large furnaces, in which feveral earthen tubes are fixed in an oblique pofition, which are filled with pyrites, the apertures of which terminate on the outfide of the furnace, and to which large receivers are fixed. It is obtained adventitioufly in the roafting of feveral ores, partly in little holes or hollows made on the furfaces of the heaps of the roafted ores, and partly by a peculiar apparatus, in what are called *Sulphur catchers*. All the fulphur produced in thefe

inftead of pitch, the volatile alkali ferves the manufactories of fal-ammoniac, and the refidue is an excellent coak. This art has been tranfported by M. *Faujas* de St. Fond, into France. [E]

† Vid. Phil. Tranf. Vol. LXXI, p. 233. I rather fuppofe him the fartheft from it. *Brand*, who has been the moft generally followed, reckons it only at $\frac{1}{16}$. It has always appeared to me that the weight of phlogifton in fulphur is almoft infinitely fmall, when compared with that of the other part. In fact, Mr. *Kirwan* founded his calculations upon an erroneous doctrine, fuppofing that fulphur was formed of phlogifton and the vitriolic acid, as has been hitherto the opinion of Chemifts in general, from the time of *Stahl* down to the prefent period, in which the fcience has received a new and brilliant light from the labours of *Lavoifier* and *Berthollet*. The former of thefe philofophers has fhewn that fulphur is converted into vitriolic acid by the abforption of pure air, or its bafe; and vitriolic acid into fulphur by the feparation of this air from it. And we hope that we have made it evident in the firft part of this Work that fulphur is compofed, not of vitriolic acid and phlogifton, but of phlogifton and a certain bafe which may be termed indifferently the bafe of fulphur, or the bafe of vitriolic acid; as with phlogifton it conftitutes the former fubftance, and with pure air the latter. [E]

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ways, is ſtill impure, of an aſh-colour,be purified. This is done by and muſt barely melting it, when the greater part of the impurities ſettle at the bottom, and are alſo in part taken off from the top, in the form of ſcoriæ. After which the pure ſulphur is caſt in moulds, in the ſhape of ſticks. The ſediment is what is called *Sulphur vivum*.

Among the principal properties of ſulphur are the following. When it is ſet upon the fire, it is eaſily liquefied, and takes fire very readily, burning with a blue flame, and at the ſame time emitting a ſuffocating acidulous vapour. In cloſe veſſels it ſublimes, and attaches itſelf to the upper part of them in the form of *flowers of ſulphur*, which, excluſively of the divided ſtate they are in, are in no ways preferable to any other pure ſulphur. The method of obtaining its acid has already been deſcribed in the Halurgy. It is inſoluble both in water and in ſpirit of wine; but on the other hand, all oils, andeven the eſſential oils, take up, though more ſparingly. By the intervention of alkaline ſalts, it however may be united with all theſe ſubſtances. Though of itſelf it unites with moſt metals, yet ſtill its combining power is in this caſe increaſed by alkali.

That the alkaline ſalts are fitteſt for the ſolution of ſulphur in their cauſtic ſtate, and that from this combination ariſes, what we call liver of ſulphur: has already been ſhewn in the Halurgy. I ſhall therefore only mention one more preparation, that may be obtained from this combination; viz. *Lac Sulphuris*, or milk of ſulphur. For this purpoſe a quantity ad libitum of the moſt cauſtic lixivium muſt be made to boil in an iron kettle, or in a veſſel of earthen ware, and as much pounded ſulphur thrown into it by degrees, as the lixivium can take up; the decoction is then to be filtered, and after it has become cool, and has been properly diluted, the ſulphur is to be precipitated from it with diluted vitriolic acid. Finally, the precipitate, which is nothing but a finely divided ſulphur of a white colour, is to be very well waſhed and edulcorated.

Next to theſe, the different *Balſams of Sulphur* deſerve alſo to be mentioned, which are prepared ſometimes with etherial, and ſometimes with expreſſed oils. In order the better to attain this end with or without the addition of an alkali in both caſes, it is neceſſary previouſly to prepare the ſulphur for this purpoſe, and to make it more ſoluble, which may be done in two different ways: 1. by converting it into liver of ſulphur, in conſequence of melting it gently together with three parts of purified alkali: and 2. by boiling one part of ſulphur with four of linſeed oil, over a very gentle charcoal fire, in a veſſel capable of containing four times

times the quantity, till it begins to riſe. At firſt the oil boils quietly only, and the ſulphur lies melted at the bottom of the veſſel, without being diſſolved. But on a ſudden the oil begins to riſe in ſuch a manner, that it can hardly be prevented from boiling over, (whence, by way of precaution, an empty earthen-ware veſſel, of a proper ſize, ſhould be placed near at hand, that part of the liquor may be poured into it); and at this very inſtant the ſulphur is diſſolved. When cold, it becomes a perfectly dry tough maſs, which is not very unlike liver, and is called *Corpus pro balſamo Sulphuris.* Now, either the former preparation of ſulphur or this may be taken in any quantity ad libitum and a due proportion of oil of aniſeed, turpentine, amber, or almonds, poured upon it, and put to digeſt ſlowly in a matras not very accurately cloſed, for the purpoſe of diſſolving the ſulphur. In this way are obtained the various balſams of ſulphur, which, according to the ſpecies of oil employed in making them, bear the different names of *Balſamum ſulphuris Aniſatum, Terebinthinatum, Succinatum,* or *Amygdalatum.* In all theſe preparations the greateſt care and caution muſt be employed in the digeſtion; as otherwiſe the life of the operator may be endangered, and the houſe ſet on fire; of which the accident mentioned by *Hoffmann*, as having happened in Zellerfeld from neglect of this, may be adduced as an inſtance. For the purpoſe of avoiding an accident of this kind, the veſſels ſhould be but ſlightly cloſed, and but a very gentle fire applied. A tall matras alſo contributes much to ſafety in this caſe; upon this a head may be ſet in order to prevent the evaporation of the etherial oil, and an unluted matras only fixed to its beak.

The conſtituent parts of ſulphur beforementioned, may be proved ſynthetically, or by compoſition. According to an obſervation made by *Stahl*, of the truth of which it is in the power of any one, every day, to convince himſelf, a genuine ſulphur, not in the leaſt different from the natural, is generated in every caſe, in which concentrated vitriolic acid is united with a phlogiſtic body by fire; at the ſame time that every particle of water is excluded. This artificial compoſition of ſulphur may principally be accompliſhed in two different ways. *Firſt*, by mixing concentrated vitriolic acid with an etherial or expreſſed oil, and diſtilling the mixture. In the beginning of this diſtillation, a conſiderable part of the acid comes over in the form of ſulphureous acid, and this as long as any moiſture remains. But towards the end of the operation, when the reſiduum is become dry, and the fire is continued, a true ſulphur is ſublimed. The *other method* by which the ſame effect is produced, conſiſts in the following proceſs: Equal parts of vitriolated tartar and alkali, or Glauber's ſalt only, are to be mixed

mixed with a fourthpart of powder of charcoal, the mixtu ris to be fused in a covered crucible, and then poured out. The mass being dissolved in boiling water, and the solution filtered, the precipitate made from it with an acid will exhibit, when edulcorated, a true and perfect sulphur. It is true, sulphur consists of the vitriolic acid and phlogiston; but this acid being volatile, would be apt to escape by the fire, before the combination with the phlogiston could take place. Besides, the sulphur also thus generated, even if the other inconvenience did not exist, would doubtless, being likewise a volatile body, fly off from the fire. Both these inconveniences are removed by the fixed alkali which is in both the neutral salts abovementioned. It prevents the escape of the vitriolic acid, and consequently promotes the union of this substance with the phlogiston; and, moreover, possesses the property of holding the sulphur in union with itself, as being a fixed body; at least to the end of the experiment, so that this substance may be separated from it. For this reason some alkali should be added to the vitriolated tartar, because the former by itself is of very difficult fusion. On the other hand, toGlauber's salt this addition is not requisite, because it fuses easily in the fire.

The rest of the acids also form with phlogiston other sulphureous bodies, which however do not appear in a concrete and solid state, but rather in the form of vapour only, and sometimes even in a liquid form. To this may be referred the nitrous sulphur*, which is produced by fire from the nitrous acid and a phlogistic body, but which is inflamed at the instant it is produced, and likewise what is called nitrous air. Other compounds of this kind are not yet sufficiently known; and several others, as phosphorus of urine, the dulcified acids, and the æthers, have already been mentioned in their respective places.

As Sulphur is one of the principal component parts of gunpowder, and, as upon this depends the whole *art of making fire-works*, I shall mention some particulars relative to it; and with them terminate the phlogurgy.

*Gunpowder* consists of a proportionate composition of nitre, sulphur and charcoal of wood, which are artificially mixed together and granulated or *corned*.

* There is no such thing as nitrous sulphur, at least in the sense that Messrs. *Macquer* and *Beaumé*, from whom the idea originally came, and our author conceive it. Nitrous air approaches the nearest to the description of a sulphur, excepting that it is not inflammable, and contains a small quantity of air, which vitriolic or common sulphur does not. [E]

The invention is commonly aſcribed to a German Monk, of the name of *Barthold Schwartz*; but Profeſſor *Beckmann* very much doubts the fact, as there is no certain account extant of this man. According to the account given of him in hiſtory, he is ſuppoſed to have lived in the middle of the 14th century; but there are earlier proofs of the exiſtence of gunpowder, ſo that it has not yet been poſſible to aſcertain with certainty the epoch of its invention. If the aſſertion of M. *de Stetten* be well founded, that in the arſenal of Amberg in the Palatinate there is a cannon which bears the date of 1303, this perhaps would be the earlieſt inſtance of the uſe of gunpowder as a means of defence; and then the date of its invention muſt neceſſarily be removed ſtill farther back.

In order to its having the requiſite *good qualities*, the ingredients ought to be the beſt and pureſt poſſible, and be taken in proper proportion, and mixed together in the moſt accurate manner. With a view to the firſt of theſe requiſites, the nitre muſt be freed from all foreign earthy particles, and from the ſalt reſembling common ſalt. The ſulphur ought alſo to be well purified, and of a pale yellow colour; the greeniſh and white ſorts are leſs pure. The charcoal muſt be well burned, and not contaminated with ſand; in other reſpects, it is indifferent whether it be made of hard or ſoft wood.

For the *proportion* of the ingredients there can be no univerſal rule. It is known by experience, that ſulphur increaſes the power of gunpowder to a certain degree; alſo that gunpowder, which abounds more in ſulphur, does not ſo eaſily effloreſce and ſpoil, neither does it ſo ſoon become moiſt; that too ſmall a proportion of charcoal makes a weak gunpowder, and that too much makes it ſlow in taking fire. A deficiency with reſpect to nitre, will prevent it from exploding with the requiſite power, and from impelling the ball to a ſufficient diſtance; a redundancy of nitre will occaſion it to attract moiſture from the air ſooner than it otherwiſe would. From this it appears, that according to the force and durability it is required to have, and the uſes to which it is to be applied, it muſt be very differently mixed. According to *Beaumé*, gunpowder prepared with ſix parts of nitre, two of ſulphur, and one of charcoal, has the greateſt poſſible effect. To this may be added, that according to *Beckmann*, in the Engliſh manufactories they are uſed to make three different kinds of gunpowder, and of each of theſe, a ſtronger and a weaker ſort, in the following proportions:

In

| | | Canon Powder | Muſquet Powder | Piſtol Powder |
|---|---|---|---|---|
| Strong | Nitre<br>Sulphur<br>Charcoal | 100.<br>25.<br>25. | 100.<br>18.<br>20. | 100.<br>12.<br>15. |
| Weak | Nitre<br>Sulphur<br>Charcoal | 100.<br>20.<br>24. | 100.<br>15.<br>18. | 100.<br>10.<br>18. |

In order that they may be accurately mixed together, the materials, after being weighed out, are to be pulverized in mills conſtructed for the purpoſe, the peſtles of which are clouted with braſs, and, during the pulverization, continually moiſtened with water, in order to avoid raiſing a duſt, and exciting too much heat. The *Meal-powder* obtained by this means, is afterwards *granulated* or *corned*, and dried.

The aſtoniſhing *effects* of gunpowder depend on the action of the nitre, or more properly, of the nitrous acid, upon the phlogiſton of the ſulphur and charcoal. The minutely pulverized charcoal receives the ſpark, is inflamed, ſpreads the fire more rapidly by means of the ſulphur, and hence ariſes the occaſion of the whole maſs. Nothing more occurs here than in every other detonation, only that it takes place in a much ſhorter ſpace of time*. Now as in every detonation,

* Gunpowder will not detonate in a vacuum. It is therefore evident that, as air muſt be preſent to begin the combuſtion, it is the charcoal which is firſt ignited, or rather that particle of the charcoal that comes into contact with the match or other ignited body employed. This particle being at the ſame time in contact with one or more particles of nitre, decompoſes them, ſets looſe the air, in conſequence of which the combuſtion becomes ſtronger, ſo that heat is generated ſufficient to ſet fire to another contiguous particle of charcoal; this decompoſes more of the nitre, the conflagration becomes general, and the decompoſition of the whole maſs is ſo rapid, though gradual, as to appear inſtantaneous. But it muſt be obſerved, that it is the extrication, not of pure air, but of mephitis, that cauſes the report: as the pure air, as faſt as it is diſengaged, is fixed again by the vegetable principle of the charcoal, and the baſis of the ſulphur forms aerial and vitriolic acid, or perhaps ſulphureous gas. But the mephitis being diſengaged, finds nothing in the whole compoſition capable of fixing it; for which reaſon the elaſtic vapour produced is chiefly mephitic gas. But the detonation of nitre with charcoal alone is evidently ſlow and gradual: it is therefore neceſſary that ſulphur ſhould be added, which kindling at a low degree of heat, makes a communication between the grains, and thereby greatly contributes to the quickneſs

tion, the nitrous acid is obſerved to be entirely deſtroyed in its action upon inflammable bodies (the nitrous acid on being decompoſed, yields dephlogiſticated air, but ſulphur and charcoal, inflammable air *) and the water and air which are found to enter into its compoſition, are at the ſame time ſet at liberty, this is preciſely what happens here. The expanſive power of theſe elementary ſubſtances, together with that of phlogiſton that is put into action at the ſame time, is in every detonation the occaſion of that violent exploſive rarefaction which overcomes every obſtacle, of which the power of reſiſtance happens not to be ſtronger than this expanſive power, and by burſting through it with aſtoniſhing violence, rends it in pieces. This too, is preciſely the caſe with regard to gunpowder. When it is fired off in the open air, the elaſtic matters being ſet at liberty, have room to diffuſe themſelves on all ſides, and therefore do not cauſe a very violent impulſe or report, in the air; but when it is fired in a cloſe ſpace, and its power of expanſion confined to one ſingle point, its whole power acts then entire and undivided upon the parts where it meets with the leaſt reſiſtance, and propels the obſtacles that cauſes this reſiſtance, with the whole aggregate of its forces. Hence enſues a proportionably rapid and forcible diviſion of the air, which is manifeſted to the ſenſes by the report and ſtroke.

In the art of making *Fire-works*, gunpowder conſtitutes the chief ingredients; but the proportion of it is very frequently varied, according to the different uſes for which it is intended. For making theſe, meal-powder only is commonly employed, and mixed with an additional quantity of ſulphur and nitre, according to the different purpoſes for which it is intended; on which account the laſt ingredient is generally brought into the form of a powder, by ſolution and evaporation, during which latter operation it is continually ſtirred.

neſs of the exploſion, which is farther facilitated by the eaſy accenſion of this ſubſtance, in conſequence of which it inſtantaneouſly diffuſes a conſiderable heat over the whole maſs, and thus diſpoſes it to ignition. [E]

* It is not true, that ſulphur and charcoal yield inflammable air. When the charcoal happens to contain inflammable gas, they yield hepatic gas, which however is not ſufficiently inflammable to account for this phenomenon. M. *de Fourcroy* has made the ſame miſtake in his explication of the effects of Pulvis fulminans, which indeed might be expected in our author, who does not ſeem throughout the whole of his work to have paid much attention to the ingenious doctrines of M. *Lavoiſier* and his coadjutors; but appears inexcuſable in M. *de Fourcroy*, who has undertaken, and that with remarkable ſucceſs, to collect and explain theſe doctrines to the Chemical Tyro. [E]

The

The mechanical operations of the abovementioned art, not belonging to this work, we ſhall only make mention of the different compoſitions which are to be made upon chemical principles. For *Fuzes*, ſeven parts of meal-powder, five of nitre, and three of ſulphur; and for *Rockets*, thirty-ſix parts of nitre, eight of ſulphur and fourteen of charcoal are to be taken; in both theſe, the intention is that the powder ſhall only be fired by degrees. For *Blue-balls*, are to be mixed together thirteen parts of nitre, three of ſulphur, $\frac{17}{32}$ parts of reſin, $\frac{7}{16}$ of ſaw-duſt, and $\frac{9}{16}$ of charcoal. *Light balls* require, for the *dry ſort*, two parts of nitre, $\frac{1}{2}$ a part of ſulphur, $\frac{3}{16}$ of reſin, $\frac{2}{3}$ of ſaw-duſt and $\frac{1}{2}$ a part of meal-powder; for the *fuſible*, eight parts of ſulphur, two of nitre and four of meal-powder. *Fire Balls* are compoſed of twenty parts of corned powder, ten of pitch, ſix of nitre, four of ſulphur, one of tallow, one of hemp and two of linſeed-oil. *Water-rockets* require eight parts of meal powder, thirty-ſix of nitre, ſeven of ſulphur, and one of reſin; as theſe particular maſſes of fire are deſtined to reſiſt the air and water, and nevertheleſs to burn for a certain time, the oleaginous and combuſtible additions are requiſite, among which, the intent of the ſaw-duſt appears to be to prolong the conflagration. Among theſe alſo may be reckoned the *Greek-fire*, which, in fact, was not invented by a Greek, but by *Callinicus* of Heliopolis, who is ſaid to have uſed it at the ſiege of Conſtantinople. It cannot be decided with certainty what it properly was, or of what it was compoſed. According to the deſcription of it given in hiſtory, it was a liquid ſubſtance that was eaſily kindled, and extinguiſhed with difficulty, which burned upon water, and was thrown incloſed in bottles and pitchers, into the enemies ſhips, by which means they were ſet on fire. It is very probable, that pitch, ſulphur, linſeed-oil, oil of turpentine or petroleum, made a conſiderable part of its compoſition.

The variouſly *coloured fire-works* depend on various additions, by which the natural colour of gunpowder, when on fire, may be altered, and in which metallic ſubſtances, for the moſt part, ſuch as antimony, zinc, marcaſite, verdigriſe, &c. are employed Thus alſo clean filings of iron produce what is called *Brilliant-* or *White fire*.

# CHAP. VII.

## The CHEMICAL TREATMENT of BODIES, with a VIEW to the ALTERATION of their SURFACES.

THOUGH the ſurfaces of natural bodies may be changed in innumerable ways, we ſhall here mention ſuch alterations only as may either be effected or explained upon chemical principles. Moſt of theſe reſpect the colour of bodies, the alteration of which depends ſometimes on the *ſubſtraction*, and ſometimes on the *addition* of certain parts.

Of the firſt kind is *waſhing*, or the external purification of bodies from filth and dirt. The common method with ſoap and ley, is founded upon the property which theſe ſubſtances poſſeſs, of diſſolving greaſe of all kinds, and of making it miſcible with water. But for other articles, which are of greater value, and cannot bear either ley or ſoap, other ſubſtances muſt be employed, which are of a more glutinous and leſs ſaline nature; ſuch as beer, barley water, whey, the yolks of eggs mixed up with cold water, malt, ſpirits, &c.

Under this head is included alſo the taking of *ſpots* and *ſtains* out of wearing apparel of different kinds. Wax, pitch, reſin, and ſimilar hard greaſy ſubſtances, with which woollen cloths may happen to be ſpotted, ought firſt to be cooled rapidly, and then be carefully ſcraped off as clean as poſſible. After this the ſpot is to be well impregnated with oil of turpentine, and held over a charcoal fire, in order that the unctuous matter may be diſſolved by the oil: the ſoiled part is then to be laid between two pieces of blotting paper, a hot ſmoaking iron put upon it, and the blotting paper removed ſeveral times, till all the greaſe is diſcharged from the cloth. The cloth may likewiſe be moiſtened with the oil repeatedly, and the ſpot be finally humected with ſpirit of wine, and rubbed till it diſappears.

disappears. For ſpots of butter and oil, the application of heat is not requiſite; but they need only to be impregnated with oil of turpentine, and then diſcharged as above. The yolks of eggs too may be uſed laſt of all for this purpoſe; likewiſe ſtrong ſpirit of wine may ſometimes be along with the above-mentioned materials.

Spots of greaſe on ſilken ſtuffs, when theſe latter will bear waſhing, may be beſmeared with the yolk of an egg, and after the ſilk has been well rubbed with the hands, waſhed out with water. Smaller ſtains may be taken out by barely putting oil of turpentine upon them, and rubbing it in well, and then diſcharging them in the manner mentioned above. In black ſilks ox-gall may be uſed for the purpoſe of diſſolving and diluting the greaſe. Likewiſe, the ſubſtance called Spaniſh chalk, white bole or ſtarch may be mixed up with water, which is to be laid upon that ſpot, and well rubbed in, then dried with a gentle heat and rubbed out again. Theſe materials may alſo be applied to woollen cloths and ſtuffs.

Varniſh, turpentine and cart-greaſe muſt be diſſolved and extracted, purſuant to the firſt method, by the aſſiſtance of heat. Stains of this kind may alſo be rubbed with the yolk of an egg and waſhed out with cold water; though for the laſt, all that art can do is generally to no purpoſe; becauſe, on account of the iron and the dirty colour communicated by it, it generally leaves a ſpot. All the before-mentioned ſtaining ſubſtances are of that nature that they only ſoil the colour of the ſtuffs, but do not deſtroy it.

There are, on the contrary, other ſubſtances which, though they do not ſoil the ſtuffs themſelves, will yet change and frequently even deſtroy their colour; conſequently the remedy for them alſo depends upon quite oppoſite materials. I mean here ſtains made by wine, vinegar, and urine.

In *ſtains made by wine*, the ſtuff ought, if poſſible, to be immediately ſteeped in clear water, the ſtain rubbed out with a clean linen cloth, and the ſtuff dried by a gentle heat. If, after this, the colour of the ſtuff is found to have ſuffered a little, a clean linen rag, wetted with a little ſpirit of ſal ammoniac prepared with ſpirit of wine, is to be taken, and the ſpot rubbed with it for ſome time with great care. In many caſes a drachm of ſalt of tartar, diſſolved in an ounce of pure water, will anſwer the ſame purpoſe, on the ſtain being rubbed with a rag wetted with it. For fear of damaging the ſtuff, a previous trial may be made upon a piece of it, or upon a very ſmall ſtain, in order to ſee which of theſe two remedies anſwers the purpoſe beſt. The ſame method of procedure is to be followed in every reſpect

reſpect for *ſtains made with vinegar*. But on the contrary, in caſe of *ſtains made by urine*, wine-vinegar, or the juice of lemons muſt be uſed.

*Yellow iron moulds* are taken out of linen in the following manner: the ſpot is wetted with water, and, according to the ſize of it, one or two drops of ſpirit of ſalt are let fall on it, and gently rubbed with the finger; when this has been done for ſome minutes, the ſtain is waſhed out with clean water, and if neceſſary, the ſame procedure is repeated once more. In order to accelerate the effect, the ſpot thus wetted may be held over boiling water. Inſtead of ſpirit of ſalt, the juice of lemons or ſalt of ſorrel may be uſed with the aſſiſtance of heat. Either of theſe ingredients alſo may be uſed for *ſtains made by ink*. The cheapeſt material, and which is juſt as efficacious as any other, is aqua fortis. One or two drops let fall upon an ink ſpot, previouſly wetted with water only, diſſolves it completely.

*Fulling* is a kind of waſhing in the great, and is performed in mills of a particular conſtruction, with a view of taking the greaſe out of woollen cloths, and at the ſame time imparting to them a great degree of ſuppleneſs and ſoftneſs. For this purpoſe fuller's earth is uſed inſtead of ſoap; but urine alſo and other things of that nature might poſſibly be employed for this purpoſe with advantage.

*Bleaching* is an operation which, with the ſame view, is performed upon *thread*, *linen*, and *cotton*. The chief of this proceſs conſiſts in the following particulars. Firſt, the raw linen or thread muſt be freed from the coarſe impurities and dreſſing by being *ſteeped* in luke-warm water. The ſecond operation conſiſts in *bucking* or *boiling*, in which the above-mentioned commodities are boiled in a a cauſtic alkaline ley in order to extract a great part of the colouring matter contained in them. The third operation conſiſts in ſpreading the goods out in the bleach-field, where they are alternately *watered* and *dried again*. By this means all the colouring oleaginous matter, which lies deeply enveloped in the ſubſtance of the flax, is evolved and deſtroyed. The bucking and bleaching are often alternately repeated. The fourth operation is *ſouring*, and conſiſts in putting the bleached linen into an acid liquor, for which whey or any other cheap acid may be uſed, and that with this view, that the earthy particles, which proceeding either from the water or the air, have by the frequent watering, been fixed in it, may be diſſolved by this means. The fifth and laſt operation is ſimply the

the *washing of it with soap and water.* After the souring, the pieces are to be washed, first with warm water, and then with soap, that by this means all the acid that may happen still to be contained in them may be extracted.

In the *bleaching of wax*, first a larger surface is given to it, by means of a particular machine, granulating or casting into very thin round cakes. In this form it is exposed to the sun, frequently watered and turned, till it has acquired a white colour. In fine weather this operation may be completed in two or three weeks. The cause of the yellow colour of wax, seems to be etherial oily particles, which slowly evaporate in the bleaching; hence the white wax is harder, and does not consume so fast in burning as the yellow*.

*Silk* and *mohair* are first well washed with soap, and afterwards cleansed with the vapour of sulphur; the same may also be practised with cotton and woollen stuffs.

Silver plate, or coins, allayed with copper, are whitened by being boiled in water with an addition of salt, tartar, and a little alum; these salts extracting the alloy from the surface of the metal, but doing little harm to the silver †. For boiling gold plate, diluted aquafortis alone may be used, and will produce the same effect. *Etching* is employed for many different purposes, as a preparatory operation, and is performed by means of various corrosive saline liquids, which must be had recourse to, according to the nature of the body that is to be etched, whether it be of wood or metal, and again, according to the particular nature of either of these materials. For this purpose sal ammoniac, vinegar, aquafortis, and vitriolic acid; as also vitriol itself in a dissolved state are made use of.

The other way of changing the surfaces of bodies, which is effected by the *addition* of other substances, consists on different *coatings*, or *coverings*, which also sometimes penetrate into the bodies, and may be distributed in a general way into *coloured*, *shining*, and *metallic*.

* Is it not rather simply phlogiston, which in this operation uniting with the hydrophloge of the water, is carried off in the form of inflammable gas; the pure air of the water remaining fixed in the wax? several circumstances conspire to render it probable that a decomposition of this kind takes place both in the wax and the water. [E]

† Vid. *Tillet*'s Treatise upon the process used by the officers of the mint at Paris, for reducing copper. In the Collection of useful Treatises, extracted from the Abbé *Rozier*'s Journ. de Physique. Vol. II. page 335. *German.* [A]

*Coloured coatings* are either fuch, by which bodies are rather penetrated than covered, or fuch as actually cover the furfaces of bodies with a colour. The former are the object of the art of *dying*, the other of *painting*.

In *dying*, the difference of the bodies to be dyed are chiefly to be diftinguifhed and confidered; next to this, the tinging materials, and laftly their application.

The different ftuffs that are to be dyed, cannot be all treated in the fame manner, becaufe they do not all imbibe the dye with equal facility. Hence the diftinction that it is neceffary to make between the dying of *linen*, *cotton*, *wool*, *mohair* and *filk*, of which the two former are fubftances belonging to the vegetable, but the three latter to the animal kingdom. Their different nature, with regard to their origin and compofition requires various preparations, in order that the colour, with which they are to be dyed, may unite with them, and acquire the greateft poffible durability. Of this difference with regard to their elementary compofition it can only in general be obferved, that the two former contain very few mucous and oleaginous, but more earthy particles; whereas, on the contrary, the latter have more mucous and oleaginous, but much fewer earthy particles in their compofition.

Moft of the *drugs ufed in dying*, are taken from the vegetable kingdom; the animal kingdom yields but very few of them; and the mineral ftill fewer; though a great many of the auxiliary materials may be taken from the latter. In regard to the nature of the real colouring drugs, they may be diftributed into *refinous* and *gummy*, and agreeably to this diftinction, require alfo fuitable folvents and preparatives. The principal dying materials are claffed into *red*, *blue*, and *yellow*, from which all the reft are produced by means of additaments; of thefe I fhall in the firft place give the names, and then mention the chemical principles to which recourfe muft be had, when they are applied to their refpective ufes.

Among the principal *red* or *fcarlet dyes*, *cochineal* deferves the firft place, as well on account of the beauty as of the durability of its colour, which however is found to be inferior in the European cochineal. Then follow *kermes* and *gum lac*; then *Brafil-wood*, *madder*, *fafflower*, *red fanders-wood*, and *archil*. Lefs known than thefe are *privet* (liguftrum vulg.), the root of the *wild madder* (afperula tinctoria), the root of *field madder* (afperula arvenfis), of *yellow ladies bed-*

*ftraw*,

*ſtraw* (gallium verum), of the *croſs-leaved ladies bed-ſtraw* (gallium boreale), of *gooſe-graſs* or *clivers* (gallium aparine), of *great ladies bed ſtraw* (gallium mollugo), of *corn gromwell* or *baſtard alkanet* (lithoſpermum arvenſe), of *alkanet root* (anchuſa offic), the root of *dyers bugloſs* (anchuſa tinctoria), the bark of the *berry-bearing alder* (rhamnus frangula), *red-beet root* (beta ruba), the root of *common ſorrel* (rumex acetoſa), *marjoram* (origanum vulgare), the flowers of *St. John's wort*, (hypericum perforat.), *ſun ſpurge* or *wart wort* (euphorbia helioſcopia), the bark of the *black thorn* or *ſloe-tree* (prunus ſpinoſa), *tormentil root* (tormentilla erecta), &c.

The principal *blue dyes* are *woad* and *indigo*; beſides theſe the juice of the *baſtard ricinus* (croton tinctorium foliis rhombeis repandis, capſul. pendul.), *litmus*, *logwood*, *elder-berries* (ſambucus ebulus), the root of the *bloody-dock* (rumex ſanguineus), *whortle-berries* (vaccinium myrtillus), the tops of *cow-wheat* (melampyrum arvenſe), *wood craneſbill* (geranium ſylvaticum), *dogs mercury* (mercurialis), &c.

It is true there are many *yellow dyes*, but few of them yield a durable colour. With regard to durability, *iron* has the firſt place among them. Then comes *arnotto* (bixa orleana), *dyer's weed* (reſeda luteola), *common ſaw-wort* (ſerratula tinctoria) *dyers green weed*, *woad*, *waxen* or *baſe broom* (geniſta tinctoria), *French berries* or *graines d'Avignon*(rhamnus infector)*fuſtic wood*(morus tinctoria),*turmeric root*(curcuma longa). Next to theſe come *looſe-ſtriſe* (lyſimachia vulgaris),*ſharp-pointed dock* (rumex acutus), the *greater celandine* (chelidonium majus), *common meadow-rue* (thalictrum flavum), the *ſweet willow* (ſalix pentandra), *narrow-leaved Canada golden rod* (ſolidago canadenſis), *rhapontic*, or *monks rhubarb* (rheum rhaponticum), *camomile with ſawed winged leaves* (anthemis tinctoria), *corn feverfew* (matricaria chamomilla), *flattened club moſs* (lycopodium complanatum), *great mullein* (verbaſcum thapſus) *fenugreck-ſeed* (trigonella fænugrecum), *Iceland* or *eringo-leaved moſs* (lichen iſlandicum), the leaves of the *birch-tree* (betula alba), &c.

The other colours are principally compoſed of the above-mentioned capital dyes. Thus from red and blue generally ariſes a *violet* colour; from red and yellow, a *flame colour*; from yellow and blue, *green*; from red and blue *brown*; *black* ſeems to be very concentrated blue. But there are likewiſe particular ſub-

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ſtances from which tints or ſhades like theſe of various colours may be produced. With regard to black, it is a general rule, that all vegetables which have an aſtringent taſte, produce a black colour with iron, to which may be referred galls, ſumach, oak-bark, the bark of the alder-tree, ſanders-wood, log-wood, the huſks of green walnuts, &c.

All theſe materials for dying do not yield their colouring matter in the ſame way, but frequently require different modes of treatment. The cauſe of this muſt be ſought for in the nature of the tinging matter itſelf, whether it be of a reſinous, oleaginous, mucilaginous or earthy nature. Next to this, it is found by experience, that a bath perfectly ſaturated with tinging matter, does not yield it to all bodies indiſcriminately, and ſtill leſs in equal quantities. Hence ariſe theſe two grand maxims in the art of dying: 1. That the colouring matter muſt be extracted from the drugs perfectly, and in a quantity ſufficient to anſwer the purpoſe: 2. that it muſt be perfectly united with ſuch other bodies as are deſigned to take the colour ſo extracted.

For this reaſon it is neceſſary that, according to their different natures, an extract ſhould be made from the tinging materials, for the proper preparation of a *bath*, by certain intermediums, in order that their colouring matter may unite with the water. Now theſe again are very various; and the ſelection to be made in the application of them, preſuppoſes either chemical knowledge, or elſe experience. Under theſe heads are included the following ſubſtances: *Alkaline*, as potaſh, the lixivium of wood aſhes, urine; *Acids*, the mineral acids, vinegar, tartar; *Neutral Salts*, alum, ſal ammoniac, marine, Glauber's and Epſom-ſalts, green, blue and white vitriol, ſugar, ſugar of lead, the ſolution of tin; and of the *Earths*, lime. But theſe ſubſtances, together with the power of extracting the colouring matter, have a very great efficacy in producing with it different ſhades or tints; whence in the ſelection of them, both theſe properties ſhould be taken into conſideration. Thus for inſtance, it is a general rule in all red colours, that they are brightened by acids, and darkened by alkaline ſalts.

Now when, purſuant to the ſecond maxim, the extracted colour is to be united to another body, or the body is to be dyed with this colour, the operator ſhould previouſly acquire a juſt notion of what paſſes in this operation, in order to be capable of making a proper choice of the materials ſuitable to the intention. In the dying itſelf, nothing more occurs than a ſeparation of the colouring matter

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from the bath, and a combination of it with the body that is to be dyed. This is effected, in fact, by an actual precipitation of the colouring particles into the ftuff that is to be dyed. Of the latter, however, there are but few that have immediately from nature this property of attracting the colouring particles from the bath, by means of fuch a precipitation. Moft of them muft firft be made fit for it by certain preparations; which in every cafe muft have a relation to the nature of the colour, to the materials ufed for the extraction of it, and at the fame time to the colour that is to be produced.

With this view the ftuffs muft firft be cleanfed from all adhering impurities, fuch as greafe, dreffing and acids, which may be done by fulling, or elfe boiling them either with water only, or with the addition of a little foap; by which means the texture of thefe ftuffs at the fame time becomes (agreeably to the intention) more loofe and fpongy. Next to this, the ftuffs before they are dyed, are for the moft part boiled up with certain fubftances, (or only fteeped in a folution of them) which, though they communicate to them no colour at all, and ftill lefs that which they are intended to have, neverthelefs fill up the fmalleft interftices of the ftuffs in fuch a manner, as to promote the depofition of the colour in them, as alfo the fhading and the durability of it. Now to this end again, according to the nature of the ftuff, the colour and the gradations of it, the beforementioned falts, and various kinds of metallic folutions, fuch as a folution of vitriol of cobalt, of fulphur of antimony, of zinc in tartar, of mercury, &c. are to be employed. By a preparatory procefs of this kind, the moft difficult combination of a colouring drug with the body intended to be dyed may frequently be effected, when the preparative is capable of affimilating this latter perfectly with the colouring fubftance. Hence it appears very evidently, how neceffary and important in the art of dying is the knowledge of the natural compofition, both of the materials for dying and of the bodies which are to be dyed, as well as of the nature and the effect of the preparatory fubftance upon both of thefe kinds of bodies.

It happens very frequently, that the colours of the ftuffs in this way prove very beautiful, but may be eafily wafhed out again, or deftroyed by the air and the fun. We fee therefore that the colouring particles are foluble, have but a fmall degree of combining power, and are deftructible. The firmnefs and durability of colours in general, confift in the difficulty of their folution, and in the great refiftance they make to the different bodies that may act upon them. Therefore when a colour is not naturally poffeffed of thefe advantages, an attempt muft be made to combine it with the ftuffs in fuch a manner, that its natural folubility may

may be leſſened by the ſubſtances combined with it, and that the colour itſelf may attain more firmneſs and durability. It happens not unfrequently that a dye is capable of being fixed on a particular ſtuff, and of continuing firm upon it; but, when applied to another, will not produce the ſame colour, neither is the colour it produces by any means laſting. In ſuch a caſe, both the bodies that are to be dyed muſt be compared together, and examined in what reſpect they differ from each other. After this the trial muſt be made, whether by the addition or ſubſtraction of certain ſubſtances, the latter cannot be brought to reſemble the former.

An inſtance of the former method of fixing a colour by art is *Macquer's* invention for dying ſilk of a durable ſcarlet colour with cochineal, which conſiſts in macerating the ſilk previouſly in the ſolution of tin, and then paſſing it through the cochineal bath. By this means he impregnates the ſilk with the particles of the tin, and cauſes the precipitation of the colouring particles of the cochineal which are otherwiſe diſpoſed to unite with the tin, to take place in the ſubſtance of the ſilk itſelf. Of the ſecond kind, is the experiment made by Profeſſor *Beckmann*, viz. that the red colour of madder may be made more fixed in cotton, by previouſly impregnating it with fat or oily particles; as by this means it is made more to reſemble ſheep's-wool in its compoſition.

An inſtance of a dye, where the colour, on the contrary, is not firmly fixed, and may be extracted again without difficulty, is the *blue turnſole* (Tourneſol en drapeau). For manufacturing this, the juice of the *baſtard Ricinus* (Croton tinctorium L.) is employed in Languedoc, where it grows wild in great abundance. The proceſs conſiſts in ſteeping various coarſe, but previouſly waſhed, rags, in the freſh expreſſed juice, and then hanging them up to dry in the ſun. Theſe rags are then ſtretched over vats covered with twigs and branches of trees, and containing urine and lime, by which means they acquire the blue colour which they now firſt exhibit. Theſe rags are then exported to Holland, where the colour is again extracted out of them with water, and finer rags dyed blue with it, which conſtitute the blue turnſole.

The bounds which I have preſcribed to myſelf in this Work, does not permit me to enter any farther into the practical part of the art of dying. For this reaſon I ſhall conclude with giving inſtructions, after M. *Poerner*, how the ſubſtances that are ſerviceable in this art may be tried.

For the purpoſe of ſuch inveſtigation, the ſubſtance is firſt to be tried, whether it be fit for dying with or not; and by what means its colouring matter may

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be beſt extracted. In order to diſcover this, it is boiled in water, and a bit of cotton, linen or woollen ſtuff, which has previouſly been well cleaned, boiled in this decoction for a certain time, rinſed out, and dried. If the ſtuff becomes coloured, it is a ſign that the colour may be eaſily extracted; but if little or no colour be perceived, we are not immediately to conclude that the body ſubmitted to the trial has no colour at all; but muſt firſt try how it will turn out with the addition of ſaline ſubſtances. It ought therefore to be boiled with pot-aſh, common ſalt, ſal ammoniac, tartar, vinegar, alum, or vitriol, and then tried upon the ſtuff; if it then exhibits no colour, it may ſafely be pronounced to be unfit for dying with. But if it yields a dye or colour, the nature of this dye muſt then be more cloſely examined, which may be done in the following manner:

Let a ſaturated decoction of the colouring ſubſtance be well clarified, diſtributed into different glaſs veſſels, and its natural colour obſerved. Then to one portion of it let there be added a ſolution of common ſalt; to the ſecond, ſome ſal ammoniac; to the third, alum; to the fourth, pot-aſh; to the fifth, vitriolic or marine acid; and to the ſixth, ſome green vitriol, and the mixtures be ſuffered to ſtand undiſturbed for the ſpace of twenty-four hours. Now in each of theſe mixtures the change of colour is to be obſerved, as likewiſe whether it yield a precipitate or not.

If the precipitates made by the pure acids diſſolve in an alkaline lixivium entirely, and with a colour, they may be conſidered as reſino-mucilaginous particles, in which the tinging property of the body muſt be looked for, which in its natural ſtate ſubſiſts in an alkalino-ſaponaceous compound. But if the precipitate be only partly diſſolved in this manner, the diſſolved part will then be of the nature of a reſinous-mucilage, which in this operation has left the more earthy parts behind. But if nothing be precipitated by the acids, and the colour of the decoction is rendered brighter, it is a mark of an acido-mucilaginous compound, which cannot be ſeparated by acids. In this there are moſt commonly more earthy parts, which are ſoon made to appear by the addition of an alkali.

When in the inſtances in which green vitriol has been added, a black precipitate is produced, it indicates an aſtringent earthy compound, in which there are few mucilaginous particles. The more the colour verges to black, the more of this acid and earthy mucilaginous ſubſtance will be found in it.

The mixture of alum, with a tinging decoction, ſhews by the coloured precipitate that enſues from it, on the one hand, the colour it yields, and on the other hand,

hand, by the precipitate diffolving either partly or entirely in a ftrong alkaline lixivium, whether or not fome of the earth of alum has been precipitated together with the colouring particles. Such fubftances as thefe muft not in general be boiled with alum, although this latter ingredient may be very properly ufed in the preparation of the ftuff.

When a tinging decoction is precipitated by an alkaline lixivium, and the precipitate is not rediffolved by any acid, for the moft part neither one nor the other of thefe faline fubftances ought to be ufed, but the neutral falts will be greatly preferable.

In all thefe obfervations that are made with refpect to the precipitation effected by means of different faline fubftances, attention muft be paid at the fame time to the change of colour which enfues, in order to difcover, whether the colour be brightened, darkened, or entirely changed.

When the colour of a decoction is darkened by the above-mentioned additions, without becoming turbid, it fhews that the colouring matter is more concentrated and infpiffated. When the colour is brightened, a greater degree of folution and attenuation has taken place in the colouring matter, in confequence of the addition. If the colour becomes clearer, and after fome time fome of the tinging fubftance is feparated, it fhews, that part of the colour is developed, but that another part has been fet loofe from its combination by the faline fubftance.

But if the colouring matter is feparated in great abundance by the faline addition, the colour being brightened at the fame time, it may be confidered as a fign that the colouring fubftance is entirely feparated from the decoction, and that only an inconfiderable part of a gummy nature remains behind united with the additaments, which is in a very diluted ftate. This is an effect of the folution of tin, as alfo fometimes of the pure acids.

If indeed a portion of the colouring fubftance be feparated by a faline addition, but the reft of the colouring decoction becomes notwithftanding darker, it fhews that the reft of the colouring particles have been more concentrated, and hence have acquired a greater power of tinging.

With regard to the proportion of the additions, the following circumftances may ferve by way of guide. When the colour of a decoction is darkened by the addition, without any precipitate being produced; no detriment can eafily arife from ufing a redundancy of it, becaufe the colour will not be farther darkened by it. But if the colour be required to be brighter, the trial muft firft be made, which is

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the proportion by which the colour is darkened the moſt, and then leſs muſt be employed of it.

When the colour of a decoction is brightened by an addition, without a precipitation enſuing, this addition can never be uſed in a larger quantity without hurting the colour, becauſe the colouring particles would be made too light, and almoſt entirely deſtroyed. Such is the conſequence of too large an addition of the ſolution of tin, or of a pure acid.

When the addition produces a brighter colour, and part only of the colouring ſubſtance is ſeparated, without a farther addition occaſioning a freſh ſeparation, ſomewhat more of it than what is wanted may be added to produce the requiſite ſhading; becauſe experience ſhews that by this means a greater quantity of tinging particles are united with the woolly fibres of the cloth, and are capable of being, as it were, concentrated in them: for which purpoſe however theſe baths muſt be boiled down. This effect is chiefly obſerved with ſal ammoniac and wine-vinegar.

When by an addition, which cauſes a ſeparation of the colouring ſubſtance, the colour becomes brighter and brighter, the more there is uſed of it; it muſt be employed in a moderate quantity only, becauſe otherwiſe more and more of the colouring ſubſtance will be ſeparated, and its tinging power diminiſhed. But when a colour is rendered dark at firſt by an addition, and afterwards, upon more of the ſame ſubſtance being added, becomes brighter, and this in proportion to the quantitythat is added, it will be found, that the darkening power has its determined limits, and that for producing the requiſite degree of darkneſs neither too much nor too little muſt be taken.

The knowledge of the natural compoſition of the colouring ſubſtances and of the nature of the colouring principle itſelf, ſeems in many caſes to require a peculiar proceſs to be followed, with a view to the extraction of this principle. I muſt confeſs that I am of opinion, that where the colouring matter is of a reſinous nature, it might be aptly enough extracted with ſpirit of wine, which method alſo might be employed in the great. Very probably a pound of ſanders- or brazil-wood, extracted by this menſtruum, would yield more of the colour itſelf, than when extracted with water; and from certain phenomena I conclude, that theſe colours might alſo be made more firm and durable.

To the before-mentioned principles alſo the different *proofs* bear a reference by which the fixity and durability of the colours, with which a ſtuff has been dyed, may be tried; of theſe ſome may be called *natural*, others *artificial*. The *natural proof* conſiſts in expoſing the dyed ſtuff to the air, ſun, and rain. If the colour is not changed by this expoſure, in twelve or fourteen days, it may be conſidered as genuine; but if it is, the contrary is allowed. This proof however is not adapted to every colour; becauſe ſome of them reſiſt it, and yet will fade in conſequence of the application of certain acids; others, on the contrary, that cannot reſiſt the natural proof, remain unchanged by theſe latter. Colours therefore may be arranged in three claſſes, and to each of theſe a particular kind of *artificial proof* allotted. The firſt claſs is tried with *alum*, the ſecond with *ſoap*, and the third with *tartar*. For the proof with *alum*, half an ounce of this ſalt is diſſolved in one pound of boiling water in an earthen-ware veſſel; into this is put, for inſtance, a drachm of yarn or worſted, or a piece of cloth of about two fingers breadth; this is ſuffered to boil for the ſpace of five minutes, and is then waſhed in clean water. In this manner are tried crimſon, ſcarlet, fleſh-colour, violet, ponceau, peach-bloſſom colour, different ſhades of blue and other colours bordering upon theſe. For the proof with *ſoap*, two drachms of this ſubſtance are boiled in a pint of water, and the ſmall piece of dyed ſtuff, that is to be tried, is put into it, and likewiſe ſuffered to boil for the ſpace of five minutes. With this all ſorts of yellow, green, madder-red, cinnamon, and ſimilar colours are tried. In the ſame manner is made the proof with *tartar*; only this ſhould be previouſly pounded very ſmall, in order that it may be more eaſily diſſolved. With this all colours bordering upon the fallow are tried in the manner above-mentioned.

Finally, ſeveral particulars remain to be mentioned relative to the *blue-vat* of the dyers, for the purpoſe of explaining ſeveral circumſtances which occur in that operation. By this term is underſtood a blue dye made in the vat in the great, conſiſting of woad, lime, indigo, madder and bran, mixed together in a certain order in a ſufficient quantity of warm water; ſome add alſo green vitriol to it. In this mixture an extremely briſk fermentation, accompanied with evolution takes place, in which, by means of the lime, volatile alkali is developed in great abundance, and at the ſame time alſo, the colouring matter of the woad and indigo is ſet at liberty and rendered fit for the purpoſes of dying.

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The compoſition and managment of theſe blue vats will ever prove nice and difficult operations to the dyer; as various phenomena occur in them, of which ſome judgment muſt be formed, even though they form it merely in an empyrical manner. Theſe vats are liable to be ſpoiled chiefly in two different ways, both of which prove very detrimental to the dyer. In a vat, which turns out well, the liquor has generally an olive colour, and, on being ſtirred, exhibits a blue ſcum; on the other hand, it ſometimes happens that one of theſe vats look black, and exhibits no veſtiges of a blue colour, and emitting a very pungent volatile ſmell, either does not dye the goods at all, or tinges them of a dirty grey colour. In this caſe, the dyers call it a *black*, or *repelled vat*. The other miſchance is, when the ſtrongeſt blue vat changes its colour all at once, and ſuddenly paſſing over from the moſt lively blue to the colour of a brown ley, emits a violent ſtench, and does not in the leaſt dye the goods that are put into it; this, by dyers, is called a *turned* or *foul vat*.

Now, with reſpect to the cauſe of theſe two kinds of depravation, a ſkilful French dyer, *Dijonval*, affirms, from experience and repeated obſervations, that the *firſt caſe*, the *blackening*, or *repulſion of the vat*, proceeds from a redundant quantity of the lime that has been added, by the too great acrimony of which the colouring particles are too powerfully acted upon and diſſolved. This he corrected merely by heating the liquor over again, by which means the acrimony of the lime was diminiſhed. The cauſe of the ſecond caſe, viz. of the *turning*, or *foulneſs* of the vat, he found to ariſe from a deficiency in the quantity of the lime added, on which account the colouring particles had begun to paſs over to a putrid ſtate of evolution. The way to correct this defect is by the addition of freſh lime, by which the incipient deſtructive putrefaction is checked, and the colouring particles are again brought to the proper ſtage of chemical ſolution. Even this however ought not to be done in too large a proportion; otherwiſe the colouring principle will again be acted upon too powerfully, and deſtroyed in the manner firſt-mentioned.

To the art of dying are nearly allied that of *ſtaining*, and the different modes of *printing*, on the ſubject of which ſome particulars are to be mentioned.

The practice of *ſtaining* chiefly takes place in ſolid and inflexible bodies; and as it is performed with different views, it is alſo differenr in its nature. Here this kind only will be conſidered, in which a body is dyed on its ſurface, or the colour,

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which it has already, is changed. It has commonly this peculiar to it, that the penetrating materials are only laid on the bodies, with a bruſh; though the latter may alſo ſometimes be boiled or ſteeped in the former without receiving any detriment. It is uſed for *wood*, *leather*, *horn*, *ivory*, and various kinds of *ſtones*. In all theſe caſes attention ought to be paid to the natural compoſition of the bodies and their properties, as well as to the nature of the ſtaining materials.

For the *ſtaining of wood*, ſharp corroſive fluids muſt be uſed, ſuch as ſpirit of vitriol, aquafortis, or a ſolution of blue or of green vitriol, according to the nature of the wood, or the ſtate into which it has been put by means of art. Otherwiſe wood may be ſtained *red*, by previouſly ſoaking it in alum-water, and then putting it into a decoction of brazil-wood in lime-water. It may be made *blue* with a ſomewhat diluted ſolution of indigo in *vitriolic* acid. It aſſumes a *green* colour in a decoction of verdigriſe, ſal ammoniac and vinegar; *black* in a decoction of galls, logwood, vitriol, filings of iron and vinegar. For *leather*, on the contraty, theſe ſharp corroſive ſubſtances muſt be avoided; becauſe its durability will be deſtroyed by them. To give them a *red colour*, the ſkins, after being properly prepared, are dipped into a ſolution of tartar and common ſalt, then put into a bath of madder, tartar, alum, and calcined oyſter-ſhells, and ſometimes alſo at laſt into a ſimple decoction of brazil-wood. Or the ſkins are ſteeped in alum-water, and afterwards ſtained with a decoction of gum lac, brazil-wood, alum and ſal ammoniac. They acquire a *blue* colour by being rubbed over with a ſolution of indigo and alum-water. They *become* yellow in a decoction of turmeric in lime-water; and *green* with ſapgreen diſſolved in lime-water. The above-mentioned baths may in like manner be uſed for *horn* and *ivory*; beſides which the diluted ſolutions of mercury, iron, copper, and ſilver may alſo be employed. Theſe latter liquors may likewiſe be laid upon all kinds of trinkets and toys made of *agate*. For the ſtaining of *marble*, coloured reſinous ſolutions in ſpirit of wine, or in etherial oils muſt be uſed, and, to promote the penetration of them into its ſubſtance, a little heat muſt be had recourſe to. In the ſame manner, *alabaſter* alſo may be ſtained with various colours, in particular *red*, with a decoction of brazil-wood and alum, *blue* with elder-berries and alum; *yellow* with ſaffron or turmeric and other liquid colours of this kind. It is in a ſimilar kind of ſtaining that the effects of common writing-ink conſiſt: for which reaſon I ſhall give a deſcription of it a place here. The following compoſition for *black ink* is equal to any that can be made: take three ounces of good galls, and one of green vitriol, mix them together and boil them in thirty-two

ounces

ounces of wine- or fruit-vinegar, and then add one ounce of gum arabic pounded. According to a recipe published in the Chemical Journal, a good *red ink* may be obtained from four ounces of levigated brazil-wood, an ounce of alum, and the ſame quantity of purified cryſtals of tartar boiled in a quart (or thirty-two ounces) of rain or river water till it is half conſumed; one ounce of gum arabic, and the ſame quantity of white ſugar muſt be added to it while yet warm.

To this head may alſo be referred the different kinds of *ſympathetic ink*, (as they are called) by which appellation are underſtood liquors, with which inviſible characters may be written, which cannot be read, till ſome other means are had recourſe to. They may, with regard to the means which are to be uſed, be diſtributed into ſix different ſorts. In the *firſt ſort*, it is neceſſary to rub the inviſible writing over with another liquid; or elſe to hold it over the vapour of the liquid. Characters formed with a diluted ſolution of gold is to be bruſhed over with a diluted ſolution of tin; a compoſion of tincture of galls with a ſolution of vitriol; of a ſolution of vitriol with a ſaturated lixivium of phlogiſticated alkali; of vinegar of lead with a ſolution of liver of ſulphur. The *ſecond kind* remains inviſible, till expoſed to the ſun. The diluted ſolutions of gold, ſilver, and mercury have theſe properties. The *third kind* becomes viſible, when a fine powder is ſtrewed over it. The writing conſiſts of tincture of galls; and vitriol, fallen to a white powder, is to be ſtrewed over it. The *fourth ſort* becomes legible, when it is held to the fire. This is effected when characters are written with vinegar or juice of lemons, or with a ſolution of vitriol, ſal ammoniac, alum, or common ſalt. The *fifth kind* cannot be read, till the paper with the inviſible writing is put into water; for this purpoſe a ſolution of alum or ſal ammoniac is uſed. The *ſixth kind* may, it is true, be made viſible like the preceding, by the application of heat; but it has the peculiar property of diſappearing again, as ſoon as it is cool, and of re-appearing every time it is warmed. This is the property of the ink made with cobalt.

The *printing* buſineſs is divided into four different branches; viz. the printing upon *cotton*, *linen*, *woollen*, and *paper*; of which the laſt again is divided into *copper-plate* and *book printing*. The chief principles of the art of *printing upon cotton* are founded on the knowledge of the different ſaline ſubſtances, and of their effects upon colours. The chief point of this art conſiſts in the various kinds of corroſives, which are boiled down with ſtarch to the conſiſtence of jelly, with which the engraved

graved plates are covered, the cotton printed, and after they are dried, paſſed through the madder bath: laſt of all they are bleached, in order to extract the colour again from the ground, which ought to be white, in which it is not firmly fixed. It is certainly a very fine art, in which there is the greateſt opportunity afforded to the ingenuity of man to diſplay itſelf. To this head alſo may be referred the fine variegated *printing of Woollen Stuffs*, for which purpoſe many variegated colours are imprinted upon woollen ſtuffs in regular figures, by means of carved forms. In the remaining kinds, dry colours mixed with oil-varniſh, are laid on by means of carved inſtruments. Theſe arts hold the middle rank, between the art of dying and that of painting.

Of the art of *Painting*, the *colours* only form the proper object of this work. According to their different natures they may be divided into *Sap-* or *Water-colours*, *Lakes* and *Earthy colours*.

*Sap* or *Water Colours* are of that nature, that they are capable of being entirely diſſolved in water, but are by no means miſcible with oils. They are of a viſcid nature, whence they ſtand in no need of any cementing ſubſtance, neither do they dry eaſily for this ſame reaſon, and are tranſparent. All colouring juices and extracts inſpiſſated by evaporation, may be uſed in this intention, as for inſtance, a decoction of Brazil-wood prepared with alum, and inſpiſſated; extract of ſaffron, *refined Brunſwick green, cryſtallized verdigriſe*, an *aqueous extract of litmus* with the addition of a little alkali, *gamboge, ſapgreen*, and the inſpiſſated decoction of the green huſks of *walnuts*. Of theſe, *Sap-green* is prepared from the expreſſed juice of buckthorn-berries not perfectly ripe (Rhamnus catharticus Lin.) by gentle evaporation, to the conſiſtence of honey. The ſap muſt be well clarified before it is evaporated. When it is inſpiſſated, as much alum, or, which is ſtill better, ſugar of lead, is to be mixed with it by little and little over the fire, as is requiſite to produce the fineſt green colour. A redundancy of theſe additions is prejudicial. The complete exſiccation muſt be made with a gentle heat, in ſaucers. The *Litmus* abovementioned, which however contains a blue ſap-colour, is prepared in the great in the manufactories of Holland. *Ferber* gives the following deſcription of it: Archil (Lichen roccella) is to be mixed with urine, lime-water, ſlaked lime, and ſome pot-aſh in ſeveral large ciſterns, which muſt be kept under ſhelter, and ſuffered to ſtand for ſeveral weeks. By this means the maſs is rendered ſoft, and paſſes over to a kind of fermentation or evolution of its particles, and of the colouring matter contained in them. Now and then it is ſtirred, and ſuffered to ſtand

mace-

macerating, till the maſs is become quite blue and is converted into a muddy kind of pulp. Upon this the whole mixture is ground in a mill conſtructed for the purpoſe, and the pulpy magma dried in moulds*. Hitherto alſo may be referred the fine *Sap-blue* diſcovered by Dr. *Struve*. In order to make this, a quarter of an ounce of indigo is to be reduced to powder, and triturated in a glaſs mortar with two ounces of good oil of vitriol. After this, four ounces of alum are to be diſſolved in warm water, to which muſt be added two ounces of a ſolution of tartar in water, or as much as is requiſite for completing the precipitation. The precipitate is then to be edulcorated and filtered; and when it is almoſt dry, the abovementioned ſolution of indigo is to be mixed with it. In this manner is obtained a fine blue colour, void of all acrimony, which may be mixed with water ad libitum, and with which ſilk, leather and bones, may be tinged of different ſhades, and which with ſome gum forms alſo a fine ſap-colour.

*Lakes* are ſuch as have a very fine earth for their baſis, the fineſt of which likewiſe do not cover well, and always continue ſemi-tranſparent; they may alſo be uſed with oil. The *red* colours of this kind are carmine, Florence lake, and lake from Madder. The *blue* are the Berlin blue, and indigo. The *green*, the Brunſwick green and its different ſpecies. There are alſo ſeveral more lakes of other colours.

For the preparation of *Carmine*, four ounces of finely pulverized cochineal are to be poured into four or ſix quarts of rain or diſtilled water, that has been previouſly boiled in a pewter kettle, and boiled with it for the ſpace of ſix minutes longer; (ſome adviſe to add, during the boiling, two drachms of pulverized cryſtals of tartar). Eight ſcruples of Roman alum in powder, are then to be added, and the whole kept upon the fire one minute longer. As ſoon as the groſs powder has ſubſided to the bottom, and the decoction is become clear, this latter is to be carefully decanted into large cylindrical glaſſes covered over and kept undiſturbed, till a fine powder is obſerved to have ſettled at the bottom. The ſuperincumbent liquor is then to be poured off from this powder, and the powder gradually dried. From the decanted liquor, which is ſtill much coloured, the reſt of the colouring matter may be ſeparated by means of the ſolution ot tin, when it yields a carmine little inferior to the other.

* Vid. *Demachy* Laborant im Groſſen, Vol. II, (being a tranſlation into German of the *Deſcription des Arts & Metiers*, with large additions by Dr. *Hahnemann*). [A]

For the preparation of *Florentine* lake, the ſediment of cochineal that remained in the kettle, may be boiled with the requiſite quantity of water, and the red liquor likewiſe that remained after the preparation of the carmine, mixed with it, and the whole precipitated with the ſolution of tin. The red precipitate muſt be frequently edulcorated with water. Excluſively of this, two ounces of freſh cochineal, and one of cryſtals of tartar, are to be boiled with a ſufficient quantity of water, poured off clear, and precipitated with a ſolution of tin, and the precipitate waſhed. At the ſame time two pounds of alum are alſo to be diſſolved in water, precipitated with a lixivium of pot-aſh, and the white earth repeatedly waſhed with boiling water. Finally, both precipitates are to be mixed together in their liquid ſtate, put upon a filter, and dried. For the preparation of a *cheaper* ſort, inſtead of cochineal, one pound of Brazil wood may be employed in the preceding manner.

*Madder Lake* which was mentioned long ago by *Neri*, and has been ſince diſcovered afreſh by *Marggraf*, is made by diſſolving two ounces of Roman alum in ſix pounds of boiling water, and to this adding two ounces of fine madder, with which the water is ſuffered to boil once or twice more, and then to ſtand for ſome time in digeſtion. The decoction being afterwards filtered, a ſolution of alkali is to be mixed with it till no farther precipitation enſues.

The preparation of *Indigo*, according to credible eye-witneſſes, is performed in the following manner in America. Firſt, the leaves of the plant *Anil*, freſh cut, are put into large vats, and covered with water; after which a ſenſible fermentation takes place, in which inflammable air is ſeparated. This continues for about ten or twelve hours, after the expiration of which time the liquor is drawn off from the herb, and put into another vat. In this it is inceſſantly ſtirred with inſtruments of the ſhape of a ſhovel, till the colouring particles are perceived to ſeparate from the liquor of a greeniſh colour, and the latter, which at firſt was green, begins to look blue, after which it is ſuffered to remain at reſt for ſome hours. In the mean time the yellowiſh part, which occaſioned the green, and was an obſtacle to the livelineſs of the blue colour, ſeparates from the ſediment, which has now partly ſunk to the bottom, and partly ſwims upon the ſurface. When the whole has ſufficiently ſettled, the yellow liquor is drawn off as low as down to the ſediment, through different cocks placed one above another. After this freſh water is poured on it ſeveral times more, and when it has ſettled, drawn off again as before. When the ſediment is thought to be ſufficiently

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elutriated or washed, it is put into linen bags, and hung up in the open air, that the remaining liquor may drain off, and the sediment become dry*.

The preparation of *Berlin Blue* has already been described at page 450, and that of the green colours at page 454. Besides these, different coloured lakes may be made in the manner above described, from all other colouring materials. And, according to *Scopoli*, there may be obtained from the fresh bark of the

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| Pear tree ——— ——— | a brown-red, |
| Oak — ——— ——— | a reddish, |
| Aspin — ——— ——— | a bright red, |
| Maple — ——— ——— | a rose-colour, |
| Hazel ——— ——— | a fallow, earth-coloured, |
| Plumb ——— ——— | a coffee-brown, |
| Hawthorn ——— ——— | a blackish, |
| Scotch fir ——— ——— | a violet brown, |
| Cornel or Dogberry-tree ——— | a brown, |
| Vine ——— ——— | a pale red, |
| Larch ——— ——— | a brown-red, |
| Silver fir ——— ——— | a reddish, |
| Linden or Lime-tree ——— | a rose-coloured lake, |

and from many other substances of this kind, which have not as yet been examined with this view. When the lakes are required to have a little more opacity, instead of alum, Epsom salt may be used.

With respect to the *coarser sorts*, *Rose-pink* is prepared from coloured whiting, with a decoction of Brazil-wood and alum. For *Dutch-pink*, the leaves of the Birch-tree, dyer's-weed, or French-berries are boiled with alum, and a proportionate quantity of whiting coloured with it. Instead of the latter, turmeric also may be used. In the same manner, from the juice of whortle-berries and lime, a *blue colour* may be prepared. These form the middle class, between the lakes and the earthy colours.

The *Earthy pigments* always owe their colouring substance to some extraneous admixture; for pure earth has of itself no colour, as is evident in the instance

* *Demachy* Laborant im Grossen, Vol. II, page 234—260.

of *chalk*. The colour in all cafes is derived from phlogiftic or metallic bodies. All earthy pigments may be divided into *carbonaceous colours*, *metalliferous colours*, and *metallic earths*.

To the *carbonaceous pigments* may be referred the *black crayons*, as they are called, which are made of the wood of the lime-tree, burned in clofe-luted crucibles; and alfo *lampblack*, or the foot of the pine, or fir-tree, which, in order to expel the unctuofity from it, muft be allowed to burn out a little in a well-luted crucible. It is mixed with thin fize, and formed into cakes, which are known by the name of *Indian Ink*. Likewife *ivory-black*, which is obtained from ivory burned in clofe veffels; and the *coal of tartar* which may be obtained of an equal good quality both from tartar and from the preffed lees of wine, and is chiefly employed for copper-plate printing.

To the *Earthy pigments that contain metal*, whofe colour is frequently derived from fome metallic earths contained in them, and fometimes, though feldom, from bituminous particles, may be reckoned *red chalk*, *yellow ochre*, the *Boles*, *Cologne earth*, *umber*, *black-lead*, or *plumbago* viride montanum, or *mountain green*, *mountain blue*, the *blue earth* from *Mount Eckard*, and *Ultramarine*. The mountain green and mountain blue are alfo obtained from fome minerals dug out of the mines at Tyrol, by picking them out, grinding them, and wafhing over the fine colouring particles*. Otherwife the latter may be obtained in the fame manner from the lapis armenus. But it is likewife artificially prepared from copper. The laft of all thefe, viz. ultramarine, is not offered to us immediately by nature, but muft firft be produced by an artificial procefs, of which the moft antient formula is to be found in *Alexius Pedemontanus*. The main part of the procefs confifts in this: A pound of the beft lapis lazuli, being previoufly freed from all impurities and extraneous lapideous matter, is to be calcined, reduced to a fine powder, and deprived by wafhing of the remaining colourlefs earthy particles. The refiduum muft then be triturated as fine as poffible with water, and dried. Afterwards, according to the moft ancient formula, refin, colophony, maftich, turpentine, wax, and linfeed-oil, of each two ounces, muft be melted together with an ounce of oil of almonds, and mixed up with the abovementioned powder. Undoubtedly the maftich here does nothing but what might be effected as well by colophony ufed in its ftead. Upon this refinous mafs a fmall portion of a clear and weak lixivium of afhes is to be poured, and thoroughly worked up with it, till a confiderable quantity of blue pigment is

* *Demachy* Laborant im Groffen, Vol. II, page 333—340. [A]

obſerved to be waſhed out; after which this lixivium is decanted off, and a freſh one poured upon the maſs, and this procedure continued, till no more of the blue colour can be waſhed out. The powder which has been waſhed out, according to the difference that is obſerved in its colour, is to be put into different veſſels, and each ſort, after it has ſettled at the bottom of the veſſel, waſhed over ſeveral times more with a freſh lixivium, and then dried, and ſet by for uſe, being firſt powdered, and levigated very fine. The metallic part of this colour is iron.

The real *metallic calxes*, which are employed as pigments, are the *common Indian red*, or colcothar, *ceruſs* or white lead, *white flake*, *tin-white*, *maſticot*, *minium* or red lead, *Naples yellow* *, *verdigriſe*, and *Brunſwick green*†. The mineriform pigments are *vermilion*, *orpiment* or *Kings yellow*, *realgar* or *ſandarach*, *aurum muſivum* and *molybdæna* ‡.

*Glaſs colours* conſiſt of glaſs of eaſy fuſion coloured with different metallic calxes. The glaſs for enamel, deſcribed before at page 390, may be employed for the baſis of them all. For a *red colour*, to one ounce of it may be added ſeveral grains of the purple precipitate of gold, or of a thoroughly-calcined calx of iron; eight grains of manganeſe alſo will anſwer the ſame purpoſe. For a *purple colour*, eight grains of manganeſe, and the ſame quantity of calx of copper are to be uſed. For a *violet colour*, the weight of the calx of copper is to be increaſed. For a *blue* colour, ſmalt alone will do. Otherwiſe this colour may be communicated to the above quantity of enamel-glaſs, with two grains of calx of copper, one of cobalt, and half a grain of manganeſe. A *yellow glaſs* is obtained from ten or twelve grains of Naples yellow, and a *green* from fifteen grains of the calces of copper and iron mixed in equal parts.

In the application of all theſe different pigments attention ſhould be paid partly to the vehicle and cementing materials with which they are to be mixed up,

* The yellow pigment, for which Mr. *Turner* has a patent, deſerves a place here. It was firſt invented by *Scheele*, and is prepared by triturating minium and common ſalt together in a mortar, and then expoſing them in a crucible to a gentle heat. The ſalt is decompoſed; the marine acid uniting with the calx of lead, forms the patent yellow; and the baſis of the ſalt, which muſt be carefully waſhed out, is the mineral alkali, of ſo much conſequence in the ſoap, glaſs, and other manufactories. [E]

† *Verditer*, a blue colour prepared with chalk, and copper precipitated from aqua fortis, is omitted in this liſt. Perhaps, though much uſed in this country, it is neglected in Germany, on account of its not ſtanding well. [E]

‡ Inſtead of *molybdæna*, in this country we make uſe of *plumbago* or *black lead*. [E]

 and

and partly to the ground, upon which they are intended to be laid. The major part of them, it is true, may be uſed as water-colours; only ſome gum-water or ſize muſt be added to them; but they are not all of them miſcible with oil. Many of them will not bear to be laid upon a lime-ground, becauſe they will entirely fade away upon it; they muſt conſequently have a chalk-ground; and alſo all the lakes require ſome other ground, becauſe they do not cover ſufficiently. In the painting with oil, the cloth is firſt of all to be covered with a ground of ſize, to prevent the colours from ſinking in. The glaſs- or enamel-colours are laid on with oil of turpentine, and burned into the pieces in ſmall furnaces.

Here alſo deſerves to be mentioned the curious invention of transferring intire from paper to glaſs the paintings that have been made upon prints. Two parts of turpentine, and one of colophony (or common reſin) are firſt to be melted together; with this, by means of a hair pencil, a glaſs plate is covered on one ſide very thin, while it is held over a charcoal fire; then the engraving, which ought to be printed upon fine ſoft paper, is laid with its coloured ſide upon the glaſs, and preſſed down upon it with a piece of cotton in every part, ſo that no hollow place may remain; and in this ſtate the glaſs is ſuffered to lie in a gentle heat for ſome days. When the whole is become perfectly hard, the glaſs is ſuffered to cool; after which the back part of the print is to be wetted with water, and all the paper carefully rubbed off with the fingers, till the operator comes quite to the colour, which ſticks faſt to the glaſs. The glaſs is then wiped dry again, and bruſhed over very thin with a tranſparent oil-varniſh, and inſtead of the paper ground covered with leaf-braſs or tin-foil. Theſe, when they are dry, may alſo have a coating given them of very ſtrong ſize *.

*Gloſſy coverings* are made in various manners; the principal are *varniſhes*, the application of which is immediately connected with the art of painting. They may be diſtributed into *gum-oil-* and *lac-varniſhes* or *lacquers*. The ſurface of painted bodies, which would otherwiſe be dull, acquire by this means a gloſſy and more pleaſing appearance.

* To the account given in the note to page 166 of the newly-invented art of engraving upon glaſs by means of the fluor acid, may here be added, that Mr. *Puymarin*, who lays claim to this invention likewiſe, and whoſe method is nearly the ſame as Count *G*'s, recommends in the *Mem. de l'Acad. de Toulouſe*, for 1786, the beſt maſtich in tears with equal parts of ſome drying oil, for the preparatory coating. [E]

By *gum-varniſhes*, are to be underſtood, either a ſtrong ſize, or a ſolution of gum arabic, with which various kinds of water colours are mixed up and laid on, and which are burniſhed when they are dry, or elſe covered by being bruſhed over with the former. All varniſhes in general ſerve to fix the colours of painting. This alſo, among others, is the chief intention of *Loriot*'s method of *fixing crayon-paintings*, which conſiſts in ſprinkling them by means of a ſtiff and very elaſtic bruſh, with extremely minute drops, in the form of dew, of a thin ſolution of iſing-glaſs in ſpirit of wine. The *varniſh* for caſts and ſtatues in plaſter of Paris is compoſed of white ſoap and white wax, of each half an ounce, diſſolved in two pints of boiling water *.

*Oil varniſhes* conſiſt of theſe ſorts of expreſſed oils, which are naturally inclined to dry, which deſcription however is farther increaſed by an artificial treatment, by which at the ſame time they acquire a greater degree of ſplendor. The chief point conſiſts in this, that by boiling they are deprived of a portion of the watery and acido-mucilaginous compound, which is firmly incorporated in their ſubſtance, or ſuch other bodies are united to them, as tend to inſpiſſate, and dry them up. This may be effected merely by ſlow evaporation; and ſetting them on fire, by which means linſeed-oil, for inſtance, may be inſpiſſated to the conſiſtence of a ſalve, ſuch as is required for the *printing of books* and *copper-plates*, to which, for the uſe of the copper-plate printers in order to give the black colour, charcoal made of vine-ſtalks is added. For the common *painting varniſh*, one pound of linſeed-oil may be boiled with one ounce of pulverized litharge of ſilver for five or ſix minutes, till the aqueous parts are evaporated. The farther additions that are to be found in many other recipes are ſuperfluous; in many caſes may occaſionally be added from one to two drachms of white vitriol, well triturated. To prevent the colour becoming brown, a few ſpoonfuls of water may be poured into the kettle, and the whole boiled till all the water is evaporated. For a very tranſparent colourleſs varniſh, either the linſeed-oil or the varniſh, after it is made, muſt be rendered colourleſs by the method deſcribed before, at page 530. For the *varniſh for oil-cloth*, this muſt be well inſpiſſated by evaporation, and a little colophony (or reſin) added to it.

* N. B. Whenever pints are mentioned in this work, they muſt be underſtood to mean *medical pounds* or wine-pints. [E]

Lac

*Lac varnishes* or *lacquers* consist of different resins in a state of solution, of which the most common are mastich, sandarach, lac, benzoin, copal, amber, and asphaltus. The menstrua are either expressed or essential oils, as also spirit of wine. For a lac varnish of the *first kind*, the common painter's varnish is to be united by gently boiling it with some more mastich or colophony, and then diluted again a with little more oil of turpentine. The latter addition promotes both the glossy appearance and drying of the varnish. Of this sort is the *amber-varnish*. To make this varnish, half a pound of amber is kept over a gentle fire in a covered iron pot, in the lid of which there is a small hole, till it is observed to become soft and to be melted together into one mass; as soon as this is perceived, the vessel is taken from off the fire, and suffered to cool a little; when a pound of good painters varnish is added to it, and the whole suffered to boil up again over the fire, keeping it continually stirring. After this, it is again removed from the fire, and when it is become somewhat cool, a pound of oil of turpentine is to be gradually mixed with it. Should the varnish, when it is cool, happen to be yet too thick, it may be attenuated with more oil of turpentine. This varnish has always a dark brown colour, because the amber is previously half-burned in this operation; but if it be required of a bright colour, amber powder must be dissolved in transparent painters varnish, in *Papin*'s machine by a gentle fire. As an instance of the *second sort* of lac varnishes with etherial oils alone, may be adduced the *varnish made of oil of turpentine*. For making this, mastich alone is dissolved in oil of turpentine by a very gentle digesting heat in close glass vessels. A varnish of the consistence of thin turpentine is obtained for *aerostatic machines*, by the digestion of one part of elastic gum cut into small pieces, in thirty-two parts of rectified oil of turpentine. Previously to its being used however it must be passed through a linen cloth, in order that the undissolved parts may be left behind. The *third sort* of lac varnishes consists in the spirit of wine-varnish. The most solid resins yield the most durable varnishes; but a varnish must never be expected to be harder than the resin naturally is of which it is made. Hence it is the height of absurdity to suppose that there are any incombustible varnishes, since there is no such thing as an incombustible resin. But the most solid resins by themselves produce brittle varnishes; therefore something of a softer substance must always be mixed with them, whereby this bitterness is diminished; for this purpose gum elemi, turpentine, or balsam of capaiva are employed in proper proportions. For the solution of these bodies the

strongest

ſtrongeſt alcohol ought to be uſed, which may very properly indeed be diſtilled over alkali, but muſt not have ſtood upon alkali. The utmoſt ſimplicity in compoſition with reſpect to the number of the ingredients in a formula is the reſult of the greateſt ſkill in the art; hence it is no wonder that the greateſt part of the formulas and recipes that we meet with are compoſed without any principle at all.

In conformity to theſe rules, a fine *colourleſs varniſh* may be obtained, by diſſolving eight ounces of gum ſandarach and two of Venice turpentine in thirty-two ounces of alcohol by a gentle heat. The following, which is obtained from five ounces of ſhell-lac, and one of turpentine, diſſolved in thirty-two ounces of alcohol by a very gentle heat, is *harder, but of a reddiſh caſt*. To theſe the ſolutions of copal and amber are undoubtedly preferable in many reſpects. The ſolution of the former is effected by triturating an ounce of powder of gum copal, which has been well dried by a gentle heat, with a drachm of camphire, and, while theſe are mixing together, adding by degrees four ounces of the ſtrongeſt alcohol, without any digeſtion. But I muſt confeſs that I never could ſucceed in this way with amber.

Between this and the *gold varniſh* there is only this difference, that ſome ſubſtances that communicate a yellow tinge are to be added to the latter. The moſt ancient deſcription of two ſorts of it, one of which was prepared with oil and the other with ſpirit of wine, I met with in *Alexius Pedemontanius* *, of which the firſt edition was publiſhed in the year 1557. But it is better prepared and more durable, when made after the following preſcription; take two ounces of ſhell-lac, of arnatto and turmeric of each one ounce and thirty grains of fine dragons-blood, and make an extract with twenty ounces of alcohol in a gentle heat.

*Oil varniſhes* are commonly mixed immediately with the colours, but lac or lacquer varniſhes are laid on by themſelves upon a burniſhed coloured ground, but when they are intended to be laid upon naked wood, a ground ſhould be firſt given them of ſtrong ſize, either alone or with ſome earthy colour, mixed up with it by lecigation. The gold lacquer is ſimply rubbed over braſs, tin, or ſilver, to give them a gold colour.

For *metallic coverings*, ſuch metals only are commonly choſen as recommend themſelves by their ſplendor, and at the ſame time are ſufficiently ductile, ſuch

* De i Secreti, Lucca, 1557.

as gold, ſilver, braſs, tin, and quickſilver; from which alſo the reſpective coverings have their names.

By *Gilding* the external ſurfaces of certain bodies are ornamented with a gold colour. It is either *ſpurious* or *genuine*, accordingly as real gold or braſs is employed for the purpoſe: the latter kind will be treated of ſeparately in the courſe of this work. The genuine kind may be ſubdivided into *cold* and *hot* gilding.

For *cold gilding* different kinds of proceſſes are practiſed; according as the gold is by various manipulations applied to the ſurfaces of bodies, either by painting, friction, waſhing, or plating.

For *painting*, *ſhell-gold* or *gold powder* is uſed. This is obtained from the reſiduum left in the crucible (after the evaporation of the quickſilver) of an amalgam made with one part of gold and eight of quickſilver: or by a long trituration of thin gold leaf with honey or ſtrong gum-water, and waſhing the honey away again with water. It is uſed alſo for genuine gold letters.

For cold gilding by *friction*, a fine linen rag is ſteeped in a ſaturated ſolution of gold, till it has entirely imbibed the liquor; this rag is then dried over a fire, and afterwards burned to tinder. Now, when any thing is to be gilded, it muſt be previouſly well burniſhed; a piece of cork is then to be dipped firſt into a ſolution of ſalt in water, and afterwards into the black powder, and the piece, after it is burniſhed, rubbed with it.

Gilding may alſo be performed by *waſhing* or *dipping*; this is effected by a ſolution of gold in aqua regia, copiouſly diluted with ſpirit of wine; with this a poliſhed piece of iron is bruſhed over, or elſe the iron is ſteeped in the ſolution. For *Grecian gilding*, equal parts of ſal ammoniac and corroſive ſublimate are diſſolved in ſpirit of nitre, and a ſolution of the gold made with this menſtruum. Upon this the ſolution is ſomewhat concentrated, and the ſilver is put into it, or bruſhed over with it. The ſurface of the metal is rendered quite black by the liquor; but, on being expoſed to a red heat, it aſſumes the appearance of golding. To this head alſo may be referred the application of gold varniſh upon ſolid or plated ſilver, with a view to give it the appearance of gold.

The gilding by *overlaying* is performed with genuine gold-leaf, which is made to adhere by means of different cementing materials, according to the nature of the different bodies that are to be covered with it. To gild the edges of books, they muſt, while the books are yet ſtanding in the preſs, be bruſhed over

very

very thin with the whites of eggs beaten up together, then covered with gold-leaves, and when they are dry, poliſhed. In lettering the backs, and gilding the binding in general, the ſtamps for the characters and other ornaments are to be applied hot upon the part previouſly covered with gold-leaf, and the remainder wiped off immediately. The *gilding of wood* is performed either upon a water or an oil-ground. In the firſt caſe the wood is well moiſtened with ſize; it muſt then be primed ſeveral times with a mixture of thin ſize and whiting, till the layer is by degrees of the thickneſs of the back part of a knife. The ſurface is next made ſmooth with ſand-leather and ruſhes, and then another ground is laid on, conſiſting of a mixture of bole armeniac, a little wax, and ſome thin ſize, and poliſhed, after which it is bruſhed over with ſpirit of wine, then covered with gold-leaf, cut into ſlips of a proper ſize, and burniſhed. In the ſecond mode, a ground, compoſed of ochre, ceruſs, and oil-varniſh is laid upon the wood, and when it is half dry, covered with genuine gold leaf, which are preſſed on to it with cotton, and when the whole is quite dry, what remains of the gold is wiped off. Our anceſtors were rather profuſe with their gold, as the gold upon old burniſhed gildings upon a chalk-ground is often found to lie pretty thick upon it. With a view to recover this, it muſt be firſt ſcraped off, the ſcrapings expoſed to a red heat, and the gold extracted by means of quickſilver.

*Hot-gilding* is performed in the very ſame various ways, but confined merely to incombuſtible bodies. For *painting with gold* upon porcelain and enamel or glaſs; fine gold-powder, or, as it is called, a calx of gold, which remains behind, after the ſubſtraction of aqua regia from a ſolution of gold, is laid on with borax and gum-water, burned in and poliſhed. For mere gilding, gold-leaf is uſed. Iron work, deſigned to be gilded, is firſt filed rough, and then after it is made red hot, gold-leaf is laid on it, and in this ſtate a perfect junction made by hammering. For glaſs, the part is covered with a ſolution of borax, gold laid upon it, and by this means melted on. The uſual mode of gilding by fire utenſils of ſilver, braſs, copper, or iron plated with copper, is done by means of a *bruſh* in the following manner. Firſt, the ſurface of one of theſe veſſels or utenſils, after being well boiled, is bruſhed over with dilute aqua fortis, in which alſo ſome quickſilver may have been diſſolved, and upon this, whilſt it is ſtill wet, ſome gold amalgamated with quickſilver, is laid on here and there, by means of a ſtift, and carefully ſpread with a bruſh equably upon every part. The veſſel is then heated under a chimney, over a charcoal fire,

 to

to ſuch a degree, that all the quickſilver ſhall be made to evaporate from the ſurface; the laying on and the evaporating of the gold, is repeated ſeveral times, according to the circumſtances. After this, it is rubbed with *gilder's wax*, which may conſiſt of four ounces of bees-wax, an ounce of verdigriſe, and an ounce of blue vitriol, expoſed to a red heat, and finally the wax is rubbed off with the ſcratch-bruſh, and the piece poliſhed with ſteel.

The ſame proceſs is in every inſtance obſerved with reſpect to *ſilvering*, with ſome few variations only. To *cold ſilvering* may be referred the boiling of ſilver-plate with tartar and common ſalt. For *painting*, genuine ſilver-powder or ſhell-ſilver is uſed; and for mere ſilvering, fine ſilver-leaf, for which however a white poliſh muſt be uſed, when the ſilvering is to have a gloſs. Copper may be ſilvered over by rubbing it with the following powder; viz. two drachms of tartar, the ſame quantity of common ſalt, and half a drachm of alum are mixed with fifteen or twenty grains of ſilver precipitated by copper, then bruſhed off, and poliſhed. *Silvering by fire* is performed in the following manner: half an ounce of ſilver, for inſtance, that has been precipitated by copper from its ſolution in aqua fortis, common ſalt and ſal ammoniac, of each two ounces, and one drachm of corroſive ſublimate are triturated together, and made into a paſte with water; with this copper utenſils of every kind that have been previouſly boiled for a ſhort time with tartar and alum, are rubbed; after which they are made red-hot and poliſhed. In this manner is done the cheap ſilvering of the ſaddlers and harneſs-makers. The above-mentioned calx of ſilver may alſo be laid on another way with borax or mercury, and made to adhere by fuſion.

The practice of *coppering* takes place in iron only. It may be done in the firſt place, by immerſing the pieces of iron, if ſmall, in a ſolution of vitriol of copper; but if they are large, they muſt be frequently bruſhed over with it. Secondly, it may be performed with copper-powder, which is laid on upon a thin covering of varniſh, and poliſhed. The *covering* or *overlaying with braſs*, which is alſo called *falſe gilding*, is chiefly uſed for wood-work. It is either glued on in thin plates, or beaten out to fine leaves, and applied in the ſame manner, and then burniſhed; or elſe laid on with gum-water by means of a hair pencil in the form of a levigated powder, upon a ſmooth burniſhed ſize-ground, and, when dry, burniſhed afreſh. This laſt is alſo uſed for writing in *golden characters*, for which, likewiſe, the *aurum muſivum* will ſerve. *Copper*-or *braſs-leaf* of different thickneſſes ſerves for overlaying, and ought to be faſtened on with different cements,

according

according to the difference of the bodies. For *gilding paper*, the paper is first of all washed with thin size, and then covered over with thin copper leaf. For *gilding leather*, which is so ancient a practice, that a description of it is to be found in the beforementioned works of *Alexius Pedemontanus*, the leather is first covered with oil-varnish, or size; after this, tin-foil is laid on, and, according to the different circumstances, an oily or spirituous gold-varnish spread over it. For setting a gilding of this kind upon wood-work, the wood must first have a ground of ochre put on it, then it must be burnished, and, lastly, covered with thin copper leaf.

*Tinning* is an operation of very ancient date, of which we find an account so early as in *Pliny*. When metallic bodies, whether of copper, brass or iron, are to be covered over with tin, it depends in every instance upon the adhesion of the substance by fusion; only the materials with which it is done, are different. The kind of tinning in use with the pin-makers is attended with solution; they being accustomed to give a white colour to their ware, by merely boiling it with tartar and filings of tin in water; in which operation a solution, precipitation and adhesion by fusion, must necessarily take place. For the tinning of iron, this latter metal is steeped in acid materials, such as whey, distillers-wash, the sour liquor of the starch-makers and the like, then scowered, and laid in melted tin, which is covered with a coat of fat, till such time as the tin has attached itself to the surface in every part. For tinning *copper*, the copper ought first to be scraped bright, then rubbed over with resin or fat, over the fire; and, lastly, covered all over with melted tin. Lately, instead of the usual way of tinning, the lining of vessels with zinc has been proposed, in order to avoid the ill consequences, which in many cases is to be dreaded from the use of the other metal.

It is true, the lustre of silver may also be produced with *quicksilver* upon copper and other base metals, but it is not at all durable, because it is soon distributed again among the particles of the metal. This metal shews its finest silvery lustre in the preparation of looking-glasses, or mirrors, when mixed with other white metals. For flat looking-glasses, a leaf of tin-foil, of the size of the glass, is spread out upon a very smooth stone table, furnished with a rim; upon this foil a quantity of quicksilver is poured sufficient to amalgamate it, a polished square of glass is then laid upon it, loaded with weights, and the superfluous mercury allowed to run off. Next to the exact evenness of the glass, which also ought

to be cleared from all greafe and duft, the chief circumftances to be attended to are, that the amalgam touch the glafs in every point, and that the mercury and tin be both very pure. For covering the convex fide of hemifpherical glaffes, in order to convert them into concave mirrors, a mould of plafter is requifite. For lining the infide of hollow glafs globes, a peculiar liquid amalgam ferves, which is compofed of tin, lead and bifmuth, of each one part to two of mercury, and is applied to the inner furface, merely by moving the glafs gently about.

To this the *preparation of falfe pearls* is very fimilar, except in the fubftance from which their filver colour is derived. This art was invented by a Frenchman of the name of *Jaquin*, who lived towards the middle of the laft century. For this purpofe, thin globules of glafs are requifite, of the fize of a pearl; into each of thefe a little drop of Oriental effence, mixed with a folution of ifing-glafs, is blown by means of a reed, and the globule fhaken round feveral times, that the effence may be fpread all over its internal furface, and give it the pearly luftre. By the name of *Oriental Effence* is underftood a filver-coloured fubftance, which is feparated by art from the fcales of the Bleak (Cyprinus Alburnus). The fcales of 4000 fifhes muft be collected, before a pound of them can be obtained, which after all yields only four ounces of pearl colour. This pearl-coloured matter is very much fubject to putrefaction, and is acted upon to fuch a degree by fpirit of wine, that it lofes all its luftre; it may however be kept in volatile fpirit of fal ammoniac.

The alteration of the furfaces of bodies is alfo the refult of the action of thofe fubftances by which fingle furfaces are brought into *union with each other*, by chemical powers. An union of this kind may be made in two different ways; either, when the edges of the bodies which are to be joined together, are put into fuch a ftate, as to be capable of exerting an attractive power towards each other, and of entering into a firm and mutual cohefion together; or, when recourfe is had to the intervention of a cementing fubftance, which is capable of cohering to both furfaces.

The firft cafe occurs in foft melted glafs, which for various purpofes may be eafily made to unite with other glafs that is already made: and likewife in the welding of iron, which when in a half-fufed and foft ftate, eafily adheres to another piece in the fame ftate of foftnefs; in which operation, the hammering contributes to the union. In like manner horn being foftened by heat, and foft

bodies

bodies acquiring a greater attractive power towards each other, in confequence of their being able to touch each other in more points than they did before, horn-plates may be united together by preffing them between hot iron tongs. For the fame reafon fmall pieces of tortoife-fhell may in like manner be joined together between hot iron plates.

With regard to the other cafe, the neceffary cementing materials are claffed, according to the different natures of the bodies that are to be united, into *flimes*, *glues*, *cements*, and *folders*.

By *flimes* are underftood fuch cementing fubftances as are foluble in fome liquid or other, at the fame time retaining their agglutinating property, whence, on evaporation of their moifture, they are capable of uniting together bodies that have been feparated from each other. They are either of a *refinous* or a *gummy* nature, according to which alfo a liquid muft be chofen for their folution.

*Refinous flimes*, in confequence of their nature, require fpirit of wine for their folution, and for this reafon are peculiarly fitted for refifting all kinds of aqueous fluids. Under this head come the cheap varnifhes or lacquers, prepared with colophony (or common refin,) turpentine, and fpirit of wine.

*Gummy flimes* require water for their folution, and therefore cannot beufed in damp places, nor for the purpofe of excluding aqueous vapours; but, on the other hand, they are ufed with advantage, where the intent is to prevent the evaporation of fpirituous fubftances. Under this head may be ranked *gum arabic*, as alfo the gums of the *cherry-plumb-* and *larch-tree*. An acid, an earth, and a ftrong phlogiftic cementing fubftance conftitute their natural compofition.

*Glues*, like the preceding, are foftened by water, but are with more difficulty brought to a perfect folution in water than thefe are, and on being dried, yield a tougher mafs and more of the nature of horn. They may be diftinguifhed into *mucilaginous* and *gelatinous glues*.

The *Mucilaginous Glues* appear to contain more earthy particles in their compofition, than the gelatinous; on which account they do not bind fo firmly, neither do they become perceptibly more liquid by heat. They are extracted from vegetables. *Bird-lime* may be adduced as an inftance of this, to which the *elaftic refin of the Caoutchouc tree* bears a great refemblance; the glue made of the inner bark,

bark of the *holly*,* *gum tragacanth*, the paste of flower or starch, the glue of *salep*, *marshmallow-root*, the fungus called *polymorphous Peziza*, (Peziza polymorpha Oederi) &c. For making *Bird-lime*, the misle-toe berries of the oak are put into a kettle, and boiled for several hours, till the decoction has acquired the requisite degree of strength. After this it is poured into water, in order that it may become tough, and then put upon a wet board, and beaten with a hard instrument, till all its kernels are separated from it, and, finally, it is washed with fresh water. To make it keep the better, from an ounce and a half to two ounces of turpentine may be mixed with it. When necessary, it may also be thinned with a little linseed-oil, or thickened with resin. When it is intended for keeping out water, some kind of grease may be worked up with it, till it begins to stick to the fingers.

The *Gelatinous Glues* seem to contain more oleaginous particles in their composition; hence they also become more liquid by heat, and bind better than the gelatinous cohesions. They are obtained from animal substances. Of this kind are ising-glass, fish, and common joiners glue, and likewise the *whites of eggs*. *Ising-glass* is prepared from the sounds and the membranous parts of different fish, is of easy solution in spirit of wine, and, mixed with a little of a balsamic resin, forms the sticking-plaster commonly called *Court-plaster*. *Fish Glue* is made from various membranous and solid parts of sea-fish, e. g. from their scales and bones, boiled down, and inspissated. *Parchment-glue* is prepared from the waste slips and clippings of parchment. And *Joiner's-glue* is produced in the same manner from various animal offals, such as shreds and slips of dressed white leather, of skins from the fell-mongers, fragments of the bones of sheep and other animals, as likewise of horn; these are boiled for a long time, then purified by skimming, and evaporated to the consistence of a thick jelly, after which they are poured out, cut to pieces, and dried in the air. The latter, when it is to be applied in small quantities, is mixed with a little sugar, to make it of easier solution; in which state it is called *mouth-glue*, or *Indian glue*.

By *Cements* are understood, such uniting substances as by length of time acquire a greater degree of hardness, are, even at first, of a tougher consistence than the glues, and are also commonly mixed with earthy particles. They are either *liquid* or *concrete*.

* This is what is with us usually sold for Bird-lime. [E]

Of *liquid cements*, the following compositions are instances: 1. litharge, lime and brick-dust: 2. litharge and brick-dust: 3. litharge, lime and fine quartzose sand: 4. litharge, red bole and quartzose sand. Instead of litharge, minium may be used. These ingredients are always taken in equal parts by measure, triturated as fine as possible, and mixed with painters--or amber--varnish. For another sort, quick-lime is mixed with fresh curds, or with old fat cheese, the white of an egg, or size; or one part of quicklime and two parts of fine quartz sand are triturated together with fresh curds; but these two latter sorts ought to be applied immediately. For *Stone-cement*, to be used in the great, finely-powdered scales of iron may be mixed with good mortar.

For the *concrete* or *fusory Cements*, the abovementioned pulverized substances are mixed with melted pitch, and applied directly, while hot; besides these, mere melted lac, or sealing-wax, may be used in many cases.

The last kind of cementing materials are the *Solders*, which, in fact, consist merely of simple or mixed metals, by which alone metallic bodies can be firmly united with each other. In this respect, it is a general rule, that the solder should always be easier of fusion than the metal intended to be soldered by it: next to this, care must also be taken that the solder be, as far as it is possible, of the same colour with the metal that is to be soldered.

For the *simple* solders, all the simple metals may be used according to the nature of the metal that is to be soldered. For fine steel--copper--and brass work, *gold* and *silver* may be employed. In the great, however, iron is soldered with copper, and copper and brass with tin. The most usual solders are the *compound*, which are distinguished into two principal classes, viz. *hard* and *soft solders*. The *hard solders* are ductile, will bear hammering, and are commonly prepared of the same metal with that which is to be soldered, with the addition of some other, by which a greater degree of fusibility is obtained, but which is not always required to be easier of fusion. Under this head comes the *hard solder for gold* *, which is prepared from gold and silver, or gold and copper, or gold, silver and copper. The *hard solder for silver* is prepared from equal parts of silver and brass, but made easier of fusion by the

* That the easier fusion of a metal compounded of gold and silver, and its application to the soldering of gold, was known so early as *Avicenna's* time, may be seen in this Author's Treatise on the *Mineral Stone*, Chap. 2. [A]

admix-

admixture of a fixteenth part of zinc. The *hard folder for brafs* is obtained from brafs mixed with a fixth, or an eighth, or even one-half of zinc, which may alfo be ufed for the hard folder for copper. The *foft folders* melt eafily, but are partly brittle, and therefore cannot be hammered; of this kind are the following mixtures: Tin and lead in equal parts; of ftill eafier fufion is that confifting of bifmuth, tin and lead equal parts; or of two parts of bifmuth, of tin and lead, each one part.

In foldering the edges of the fubftances to be foldered, muft be brought into contact with each other, the foldering laid upon them, and melted on to them. In which operations, at the fame time, both parts muft be prevented from calcining. Thefe views are attained partly by means of fal ammoniac and borax, and partly by colophony or common refin, pitch, &c.

# BOOK II.

## OECONOMICAL CHEMISTRY.

IN this our chemical knowledge of natural bodies is applied to the discovery of the most advantageous modes of obtaining and employing organized substances, in so far as these latter concern the husbandman. Consequently the principal object here is *rural Oeconomy*; which comprehends the *tillage of fields* and the *cultivation of gardens*, together with the *management and breeding of cattle*.

With regard to the *cultivation of Vegetables* in general, the following principles are universally to be observed. The thriving of vegetables depends, first, upon a *fertile soil*, in which they may take root, and whence they may derive their nourishment: and, secondly, upon a sufficient quantity of good *sap*, by which the vegetables must, in fact, be nourished. Both these man is able to procure, by labour and industry. But besides this it is requisite that the *heavens* should be *favourable*, a circumstance which is not in the power of man, and consists in a suitable disposition of the weather, by which is understood a good wholesome air, with a due proportion of rain and sun-shine.

From what has been said it follows, that the *soil* itself should be considered in two different ways. In fact, for a *soil* to be *fertile*, it is requisite: 1. That, considered as earth, it should be of a *mixed kind*, consequently it must consist of different kinds of earths, which may be called the natural composition of it; but besides this it is necessary, 2. that it should contain a sufficient quantity of soluble nutritious particles. Upon its mixed nature, depend the requisite properties of such a soil, viz. that it has the proper degree of cohesion, retains moisture moderately, and does not resist too much the ingress of air and heat into it. In such a soil none of the simple kinds of earths must predominate in any

considerable degree. Its situation next comes under consideration, whether it be situated high, and consequently much exposed to air, or low, and therefore liable to be overflowed by water; or whether it enjoys a fertilizing moisture from waters flowing in its vicinity.

But a fertile soil thus mixed by nature, is not to be met with every where upon the face of our globe. Frequently one or the other kind of earth is perceptibly predominant in it. Hence all original and natural soils, with regard to their cohesion or composition, may be *discriminated* in a general way, into *calcareous, argillaceous, sandy* and *well-mixed soils*. Each of these has its advantages and disadvantages.

A *Calcareous* or *chalky* soil is not particularly favourable to vegetation, and, indeed, is seldom met with *. It is heavy, and therefore prevents, in a considerable degree, the tender fibres of the roots of vegetables from spreading. For the same reason it is but slowly penetrated by moisture, but on the other hand, it retains it also for a longer time.

A *Clayey* soil, though easily softened by water, does not readily part with this fluid again, but retains it for a long time, till by degrees it evaporates. For this reason a soil of this kind is called by the Farmers a *cold soil*. It is besides heavy at all times, and when at last it is quite dried up, it becomes too hard, runs into cracks and fissures, and by this means is prejudicial to the vegetables that grow in it.

A *Sandy* soil, though for want of cohesion, it readily absorbs water, does not however become loose by this means, but rather more compact, and nevertheless soon parts with this fluid again. Add to this that it takes more heat than any other soil; hence it is commonly the soonest of any deficient in moisture. But as on account of the looseness of its texture, and the ease with which it is heated, it does not hinder the spreading of the fibres of roots, and promotes exhalation, it may, in a moist situation, or in a moist season, be more fertile than other soils; but in other respects it has considerable defects.

A *duly proportioned and well mixed soil* consequently must unite in itself all the abovementioned good qualities, in order to be adapted to the growth of many different kinds of vegetables. For a deficiency of any one of the former kinds, when it is mixed with another sort, ceases to be a defect, and even produces advantages.

* The author here in all probability confines his obsevation to his own country. In this a chalky soil is notoriously far from being uncommon. [E]

advantages. The proportion of ſuch a compoſition as will anſwer univerſally cannot be well determined. In moſt caſes equal parts of calcareous earth, clay and ſand appear to be the propereſt mixture.

Notwithſtanding this, experience ſhews, that in each of the abovementioned ſoils, whether good or bad, different vegetables thrive well, to whoſe nature ſuch ſoil is adapted, a circumſtance to which undoubtedly the nature of the climate may alſo contribute. A *ſandy* ſoil is very well adapted to certain vegetables, which ſpread their roots far around, are of a dry, reſinous and aromatic nature, and of a rapid growth; and alſo for ſuch, as either perſpire much, or elſe, according to their different natures, attract large quantities of moiſture from the air. In a *chalky* ſoil, various vegetables of a dry woody texture are capable of growing. In a *clayey* ſoil, ſuch will thrive as are of a ſlow growth, have ſolid and ſtrong fibres, and contain either acid or aſtringent particles in their compoſition. A *mixed* ſoil, on the contrary, is fit for growing almoſt all kinds of vegetables. For this reaſon, the plants that are to be cultivated, muſt either be choſen ſuitable to the natural properties of the ſoil, or the ſoil adapted to the nature of the vegetables.

This artificial alteration of the ſoil may be effected in three different ways: 1. Either by procuring for it the neceſſary moiſture, or by ſubſtracting that which is ſuperfluous: 2. by labouring it well, and looſening its ſurface by plowing; and, laſtly, by ſupplying the deficiency in its natural compoſition by the admixture of other proper kinds of earth. In the firſt caſe, a convenient ſituation is certainly requiſite, in order that the ſuperfluous moiſture may be carried off by means of drains and trenchches; and that this moiſture do not proceed from land-ſprings: or elſe that, on the contrary, an afflux of rain-water from the neighbouring hills be poſſible. The method laſt indicated, on account of the expences attending it, can only be executed in an inconſiderable degree, and hence can be employed merely for ſuch vegetables as do not ſtrike their roots deep into the ground.

But ſtill all this is not ſufficient of itſelf to render the ſoil fertile; for beſides this, ſuch a ſoil ought to be replete with *nutritious particles* from which the vegetables are, in fact, to acquire the whole of their growth. Now in order that the plants may be able duly to obtain theſe from the earth, and extract them, it is neceſſary that the ſoil ſhould be poſſeſſed of the requiſite degree of coheſion and poroſity and looſeneſs.

 But

But these *nutritious particles* of vegetables chiefly consist of a mucilaginous-saline compound, soluble in water; and containing a large proportion of oleaginous and phlogistic particles, which being extracted from the earth by means of water, are introduced into the vegetables through their roots, and being diffused throughout their whole substance, are secreted and changed into the several different juices and solid parts of the plants. This is the reason, why neither *water* alone, nor even a *meagre poor earth* combined with *water*, can without other admixtures promote vegetation. Some kinds of vegetables, it is true, may be made to vegetate with water alone; but it is also a fact, that they never arrive at that perfection, as when they have stood in a fertile earth, because the former is possessed of very few nutritious particles. Water is requisite to vegetation, in so far only, as by its means the nutritious particles from the earth are dissolved, and transported into the substance of the vegetables.

Moreover, it is in consequence of these nutritious particles, that what is called *mould*, by which term is understood, a porous, black and fertile species of earth, copiously impregnated with the putrified parts of organized bodies, promotes vegetation much more than an exhausted and worn-out earth; farther, that by *dung* or manure, which, in fact, contains the abovementioned nutritious particles, though as yet in a crude and undeveloped state, fertility may be imparted to any poor soil, or a soil that is already fertile, may be improved. These materials consequently must necessarily be added to every soil in proportion to its exigencies, or according to what the nature and the quantity of the plants that are to be cultivated in it, require *.

When

* The proper food of plants appears from every consideration to be the vegetable, or organic principle. This they get either from other plants, in which this principle is developed by the process of putrefaction, or from animal substances under similar circumstances, or lastly from the aerial acid, of which this substance constitutes the basis, and which, on account of its possessing a greater specific gravity than common air, is always near the surface of the earth, and consequently in readiness to be absorbed by the plants. Hence we see, that the alpine plants, viz. such as grow upon high hills and mountains, are of a much smaller size than the vegetables that grow in an equally poor soil in the valleys: the atmosphere in that elevated situation containing a very inconsiderable portion of aerial acid. *Ex nihilo nihil fit*, is an axiom of incontrovertible authority, not only in Physics, but every other department of Science. If it be not from the source abovementioned, whence comes the growth of vegetables in distilled water? and particularly the vast increase of the vegetable principle, whether in the form of sugar, farina, oil or mucilage? In the bulbous plants, indeed, this principle appears to be chiefly furnished

When therefore we conſider the nature of a good and fertile mould, and compare it with a mere ſwampy bog and mooriſh peat-ſoil, which contains a portion of acid, we diſcover a conſiderable difference, and likewiſe the cauſe, why theſe latter are not fertile in themſelves; but the principles alſo are eaſily diſcoverable, upon which ſome of them may be rendered fit for culture, and others uſed as manure. At all events, ſuch ſoils as theſe in their natural ſtate, are favourable to the vegetation of thoſe plants which are of a quick growth, and require for this reaſon a conſiderable quantity of moiſture.

With regard to dung, the *difference* alſo between the different ſpecies of it remains to be conſidered, which difference depends entirely upon the quantity of oleaginous and phlogiſtic particles, contained in the ſoluble mucilaginous compound inherent in it. Conſequently the richer the dung is, the hotter it will be in effect. Hence the dung of birds, which moſtly feed upon ſeeds, forces more than horſe-dung, (in which latter attention ought to be paid to the quantity of oats theſe animals have eaten) and this again forces more than cow-dung.

furniſhed by the bulb or hybernaculum; which is always of a farinaceous nature. In mint too, concerning the growth of which in diſtilled water ſo much has been ſaid, the addition made to its bulk may in a great meaſure be accounted for by the decompoſition of water: as this plant contains a large portion of etherial oil, that is of hydrophloge and phlogiſton; but a very inconſiderable quantity of farina, ſugar, fixed oil or mucilage: and if this plant ſhould be found to receive a very trifling acceſſion of ſubſtance (and particularly of ſuch matter as contain the vegetable principle) when tranſported to very high and barren mountains, to which the aerial acid has very little acceſs, and kept in a proper degree of warmth, the portion laid down here would be further confirmed by experiment; an experiment as eaſy to be made (by perſons properly ſituated for it) as it would be deciſive and extenſive in its conſequences. But, to return to the charge; whence then proceeds in moſt plants this vaſt acceſſion of vegetable matter? Not from the air, I mean the pure air of the atmoſphere; nor from the mephtis that is conſtantly mixed with it in the atmoſphere; for theſe are ſimple ſubſtances; and in every change they undergo, and from every combination they have entered into, may always be recovered in their original form. Neither can this matter proceed from the fixation of light in the plant, for that conſtantly produces phlogiſton, nor, finally, from the decompoſition of water; for this produces hydrophologe, which, combined with light or phlogiſton, generates inflammable gas, and, (with the addition of the vegetable principle in different proportions) oils, reſins, and the green colouring matter exhibited by the leaves and ſometimes the ſtalks and other parts of almoſt all vegetables that have been expoſed to the light during vegetation. Both in the decompoſition of water and in that of fixed air by plants, the pure air is ſeparated by the excretory veſſels at the upper ſurface of the leaves, and makes it eſcape into the atmoſphere. [E]

In

In these particulars consist the *general principles* of the cultivation of vegetables, in so far as this can be effected by human industry; but to this also may be added as a principal agent, the influence of light or heat, and of the air by which the ascent of the sap, the developement of the organized form of each vegetable, and (by the deposition of solid particles on the internal parts) its increase and growth to the destined size are promoted. Now these principles are applicable to the arts of *agriculture* and *gardening* as follows.

The object of *agriculture* is the cultivation of various kinds of corn, herbs for forage, and different other kinds of useful vegetables, which require to be cultivated in great quantities, and of which the major part will not keep more than one or two years.

With this view the soil must be prepared and rendered fertile, both by *mechanical* and *chemical* means.

The *mechanical preparatives* consist in operating upon the surface of the land, by *ploughing*, *harrowing*, *digging*, and in case of its being marshy, by making *drains* in it, or drying it up. The operation of *ploughing* is attended with a fourfold advantage: 1. that the soil is loosened; 2. that it enjoys the fertilizing influence of the air, in consequence of the loosened earth attracting fresh air: 3. because, as the soluble nutritious particles of the earth are constantly carried downwards by the rain, the earth that is most impregnated with these particles, is by ploughing brought up to the surface, so that it may be the better made use of: 4. by this means the stubble and weeds are buried in the earth, in order that they may rot there, and the soil get back again the nutritious particles contained in them. For this reason, the ploughing ought to be repeated two or three times before the seed is put into the ground. The land may also be ploughed deep in some grounds with advantage; though this practice is evidently prejudicial in others, in which, underneath a thin fertile surface, there substs a less fertile soil. Neither therefore is the *digging* of lands, in which way the earth is penetrated to a greater depth, advantageous in all cases, it being principally necessary only, where vegetables are to be sown, whose roots penetrate a considerable depth into the earth. With regard to the making of *drains* and *trenches*, in order to diminish the moisture, it must be observed, that the moister and lower a land lies, the more ditches it should have, and the higher it lies, the fewer. Moreover, in the drying of swampy lands, and making them fit for tillage, it is advisable, with a view to absorb the redundant acid contained in it, to plough in a

calcareous earth of ſome kind, the aſhes of the ſoap-boilers, and other ſimilar matters.

The *Chemical* preparation or melioration of a tract of land conſiſts, on the one hand, in the artificial production of the *compoſition* or *elementary mixture* neceſſary for it, or of that kind of coheſion, which a fertile ſoil naturally ought to have; and, on the other hand, of imparting *nutritious particles* to it, or augmenting the number of them, accordingly as either the nature of the ſoil or the vegetables that are to be cultivated in it, require.

In the firſt of theſe views, conſequently, when the requiſite compoſition does not naturally ſubſiſt in the ſoil, it is neceſſary to produce this by mixing with the ſoil other kinds of earths fit for the purpoſe. This may be eaſieſt done when theſe kinds of earths, as is ſometimes the caſe, do not lie deep under the ſurface of the true ſoil; thus ſometimes a clayey ſoil is found underneath a ſandy one; by the commixture of both which a fertile ſoil may be produced. Here nothing more is requiſite than ploughing or digging to a tolerable depth. The affair is ſomewhat more difficult, when the earths that are to be mixed with the ſoil muſt be fetched from ſome diſtance. But, when the earths are not to be found within a moderate diſtance, ſo that the expence would amount to more than the profit, in this caſe nothing more can be done by art.

*Sand* or a very *ſandy earth* do not of themſelves contribute eſſentially to the vegetation, becauſe they poſſeſs no ſoluble parts. They can both only accidentally prove of ſervice, when they are mixed with *clayey* and *marſhy ſoils*, in as far as they diminiſh their ſtiffneſs and hardneſs, promote the exſiccation of them, and gives them more warmth. A *looſe turfy ſoil*, by the weight of the ſand is made more compact, and conſequently fitter for uſe. But as mere ſand cannot be perfectly and uniformly diſtributed among moiſt clay, in this caſe ſome other ſandy earth is frequently preferable for this purpoſe.

*Clay*, or an *earth mixed with much clay*, promotes fertility alſo, ſo far only as it is mixed with a looſe and porous chalky or ſandy ſoil, becauſe their coheſion is ſtrengthened by this means, and they are made fit to retain moiſture ſomewhat longer. The clay muſt be laid in lumps upon the land, with which it is to be mixed, in order that it may be diſſolved by the rain and uniformly mixed with the reſt of the ſoil. Clayey earths, which are found rather in a dry powdery ſtate, may be ploughed in. Baked clay loſes its coheſion and ſtiffneſs; hence walls of burnt loam may be employed inſtead of a poor ſandy earth, in other moiſt and ſtiff ſoils.

*Chalky-*

*Chalk* or *calcareous earths*, on account of their natural dryneſs, are very much diſpoſed to attract both moiſture and acids; they may therefore be ſucceſsfully mixed with boggy and clayey ſoils, where they prove of ſervice in three different ways. They diminiſh its ſtiffneſs, imbibe moiſture and acidity, and give more warmth to the ſoil. Muſcle- and cockle-ſhells, when bruiſed ſmall, may be uſed inſtead of crude calcareous earth; hither alſo may be referred the calcareous aſhes of the ſoap-boilers and the elixated aſhes of the manufacturers of pot-aſh. Burned calcareous earth or lime would prove too expenſive, neither indeed is it neceſſary for the mere melioration of the compoſition.

*Gypſum* in the form of powder has ſometimes been highly celebrated in many countries as a means of promoting vegetation. Its utility in all probability has been ſhewn only relatively to a certain kind of ſoil; as an univerſal manure it can hardly be recommended. In one reſpect it may act as a mere meagre earth; but beſides this, it may alſo as a ſoluble earth enter into the compoſition of the proper nutritious parts of vegetables, and help to promote their growth, by the addition of ſolid matter. It is ſtrewed ſhortly after or before rain, or in general, when the leaves of the plants are wet with rain or dew, upon meadows in February and March, as ſoon as the ſnow is melted; and upon ploughed land ſoon after the ſeed is put into the ground, in the ſpring or autumn; and upon other field-plants, ſuch as coleſeed, turnips, pulſe, and clover, while they are young. It is ſtrewed as thick as rye is uſually ſown, and ſometimes twice as thick, and muſt be repeated annually. It is chiefly ſerviceable upon dry, light, and hot ſoils; while, on the contrary, upon cold, ſhaded, or wet ſoils it is prejudicial. It is a ſure and eaſy remedy againſt the fleas that infeſt vegetables, ſnails and mice.

*Pure marle*, and earths of the *marley kind*, may be employed in various ways, according to the various differences in their compoſition. The former of theſe, conſiſting of equal parts of clay and chalk, may in reſpect to the clay it contains, be of ſervice on a looſe light ſoil; but by virtue of its calcareous earth may alſo, when added in ſufficient quantity, looſen a heavy ſoil. The other kinds of marle, which ſhould be claſſed, according to their various admixtures, into *calcareous- gypſeous- argillaceous-* and *ſandy-marles*, may be uſed for the ſame purpoſes as the purer kinds of theſe earths themſelves. At the ſame time as theſe are mixed earths, they are more eaſily mingled with each other in the great, than chalk, clay, and ſand are. The more ſolid ſorts of them, before this

mixture can take place, muſt be left during a certain time in the fields, to fall to pieces by expoſure of the air.

From the repeated good effects which has been obſerved to attend on ſimilar mixtures of the different kinds of earth, ſome have falſely imagined, that theſe bodies are actual manures; nothing however can be more erroneous than this ſuppoſition. All ſeeds and vegetables ſtand in need for their growth of certain ſubtile and ſoluble homogeneous ſubſtances, by the actual acceſſion of which they can ſolely be ſupported; and theſe are certainly neither mere earths nor ſalts. Though it has been proved, that all vegetables receive a nutritious matter by their branches and leaves; nevertheleſs, experience ſhews, that this is not ſufficient for the profitable cultivation of them without an appropriated and more ſubſtantial nutriment. Hence it is a maxim confirmed by experience, that to every fertile ſoil ſhould be reſtored, from time to time, the nutritious particles, which it yearly loſes; and this is effected by *natural* and *artificial* manuring.

The *natural manure* of the earth can, in fact, only be ſought for in thoſe ſubſtances, which are introduced into it, partly by rain impregnated with electrical matter, and partly by the phlogiſtic particles of the air; for the better reception of which, in moſt countries, the land is *laid fallow* every third year, (that is, ſuffered to lie unſown) and ploughed three times. In this looſened and porous ſtate it is impregnated with the moſt efficacious and ſubtle elementary materials of nature, in order that in the ſequel, by means of the groſſer and more ſolid kinds of artificial manure, it may produce the requiſite quantity of vegetables. Under this head likewiſe may be compriſed thoſe vegetables, which during the land's lying fallow have grown upon it, and are ploughed in again. For though they have in part derived their growth from the nutritious particles that were ſtill in the earth, it cannot be denied on the other hand, that during their growth they have attracted many ſuch particles from the air, which they now bring to the ſoil, together with the principal, by way of acknowledgment for their board. Hither alſo may be referred the falling leaves, and the wood that rots in the foreſts.

Experience nevertheleſs has ever ſhewn, that, in an induſtrious ſtile of agriculture, in which the land is expected to produce from ten to twenty-fold crops, this natural manure is not ſufficient, neither can it yield the quantity of ſolid matter requiſite for this purpoſe. When we conſider, that one buſhel of ſeed that has been ſown in a field, produces at harveſt-time as much as eight horſes can draw

 away,

away, we muſt be convinced that to produce this effect, a great number of ſolid nutritious particles are required from the field. Theſe therefore the field muſt neceſſarily part with, and from time to time receive again by artificial manuring, that it may not at laſt be exhauſted, nor rendered barren.

The moſt uſual *manure*, which is undeniably preferable to any other, is the produce of *dunghills*, that are replete with all ſorts of animal excretions, and conſiſt of vegetables inclined to putrefaction and of mucilaginous, ſaline and oily particles. The ſuperiority of it proceeds from the food taken by the animals. Beſides this, all animal parts in general, and every thing elſe that is capable of being diſſolved by putrefaction, will anſwer the purpoſe; as the clippings of ſkins, hair, ſhavings of horn, blood, feathers, bones, weeds of all kinds, ſaw-duſt, ſoot, mire, the dirt and mud of the ſtreets, &c.

What are we then to think of the *ſaline manures* or what are called *manuring ſalts*, of which from ten to twenty pounds are ſtrewed over an acre, and are to continue to have effect for many years? Should even this whole quantity of ſalt be converted entirely into nouriſhment, and enter into the plants, yet ſtill it would be impoſſible, without extracting other ſolid ſubſtantial parts from the ſoil, to grow ſuch a quantity of corn every year, if the loſs were not reſtored to it with the ſame quantity of ſolid matter by way of rent. That which has a juſt title to be called manure, muſt actually yield to the vegetables a large quantity of ſolid nutritious matter, and this matter muſt be of a ſoluble, mucilaginous and oily nature. This, howewer, ſalts cannot do, from their very nature. The whole effect of them conſiſts in this, that they put all the oily particles which are left behind after the putrefaction of animal and vegetable ſubſtances, into a ſaponaceous ſtate, and render them miſcible with water, by which means they may the more conveniently be introduced into the vegetables as nutritious particles. With this view, therefore, *vegetable aſhes*, as alſo *lime* fallen to pieces and ſlaked in the air, as well on account of their alkaline effects, as alſo for obtunding acidity in boggy or marſhy ſoils, may, together with other uſual means, be employed for drying the lands. The *manuring ſalts*, as they are called, which conſiſt either of ſoap-boilers leys, or of the mother-water of nitre or of common ſalt boiled down, can do nothing more, whether mixed with lime or not, than aſſiſt in rendering thoſe nutritious particles ſoluble, which muſt be already contained in the ſoil, or at beſt attract the moiſture of the air, and by this means keep the ſoil a little more moiſt. But in other reſpects, ſhould the land contain no nu-

tritious particles, they are incapable of imparting any to it; consequently he who thinks that without any other substantial manure, he may manure his fields with the above-mentioned salts alone, that is, give the soil nourishment, will always find in the end, that he was mistaken.

From the same consideration it is plain what degree of credit is to be given to some husbandmen who pretend to give, by means of different *steeps* which have been proposed, a greater fertility to the seeds they intend to sow, which, by the power thus imparted to them, shall not only come to maturity, but also produce an abundance of grain. According to every rational principle this is a mere chimera; because it is quite impossible to impart such a quantity of nutritious particles to the seed, as the vegetable, which is to be produced from it, requires for its nourishment. Therefore, in agriculture, with regard to the means of nourishing the plants, our chief attention should be directed towards the augmentation of the richness of the soil, and to the perfect tillage of it. The saying of the antient Roman, *Cato*, has hitherto been constantly confirmed by the experience of ages. "What is to be done in the first place in order to cultivate a field properly? "---Plough it well. What next?---Plough it. What in the third place?--- "Manure it, plough it strait and even, and at a proper time." * In one single case, viz. in that of the *smut* of wheat only, is this practice likely to be of any service. Of this it is affirmed from repeated experience, that it is prevented by moistening the seed with lime-water, or with a caustic ley, the day before it is sown. The cause of which may be, either that the pernicious grains are by this means prevented from growing, or that certain insects are prevented from damaging the grain, when in the earth, and thus from occasioning this evil, or that the insects, which are already present, are destroyed by it.

In the cultivation of the different kinds of vegetables the first thing to be considered is, which of them require the greatest quantity of nutritious particles, and after this the quantity of the seed, necessary to be sown, should be determined. Thus, for instance, tobacco requires a soil manured with an exceedingly large quantity of dung; rye and wheat a moderate quantity; barley and oats are sown on a soil which has already produced rye; oats will grow even upon a stony

* *Cato* de re rustica, Quid est agrum bene colere?—Bene arare. Quid secundum?—Arare. Tertio?—Stercorare. Agrum frumentarium cum ares, bene et tempestive ares, sulco vario ne ares.

foil. Befides, the length of time that a vegetable is to remain in the field fhould alfo be taken into confideration. The longer it is to remain there, the more the foil ought to be prepared, loofened and manured. Madder does not by any means require an extraordinary good foil. It thrives in every foil, where ftrong rooted plants, fuch as potatoes, turneps, carrots, and the like, fucceed. The beft roots, and thofe which contain the greateft quantity of colour, are produced in a light and fomewhat moift, clayey, fandy foil. The foil deftined for it muft be ploughed deep, be loofe and mild, and manured half a year before-hand, that the dung may have time to rot. With refpect to many vegetables, the parts muft alfo be confidered which remain in the foil, fome of which, like the roots of clover, ferve for frefh manure, and fome greatly loofen the foil, as is the cafe with madder. Hence it is obferved, that all kinds of grain will thrive in a foil where madder has grown.

Finally, there are two forts of worms which are the hereditary foes of corn; from thefe it is to be in particular fecured when it is laid up. This end is beft attained by drying the grain thoroughly before it is carried to the granary, in kilns built for the purpofe. Next to this, lofty granaries, and frequent turning the grain, beft anfwer the purpofe of keeping it. There are befides a great many prefervatives againft both forts of corn-worms; but I know of none that I can recommend from certain experience; thofe that ftand in need of them, may have recourfe to books of agriculture and rural oeconomy, where this fubject is treated more at large, and try them himfelf.

Among the products of rural oeconomy, the cultivation of *tobacco* and *flax* conftitute two very important branches of bufinefs. For the cultivation of *tobacco*, the foil ought to be well dug, and, where it is practicable, manured well with fheep's-dung. The firft thing to be done, after the tobacco is got in, is to range the leaves near each other, in order that they may fweat, and by this means acquire a yellowifh-brown colour, which takes up fome days; they are then to be ftrung together. The leaves being ftrung, and hung up in large barns, are then fumigated, the fhutters being clofe fhut up, and by this means they are, on the one hand, kept from rotting; and on the other, fhrivelled up, and at the fame time freed from the crudity and rawnefs they had at firft. The fumigation is repeated again, in the fpace of a fortnight; and the tobacco, as foon as it is dry, tied up in bundles. The intrinfic value of this article is faid to be increafed, by packing the leaves up very tight in boxes or cafks in the month of

March

March, and suffereing it to ſtand ſo for the ſpace of a year or more, by which means it is ſaid to loſe its diſagreeable ſmell and taſte.

The preparation of *Flax* conſiſts in ſteeping it in water, whilſt it is yet freſh, in order that the mucilaginous and gummy particles of it, which glue the fibres of its bark together, may be diſſolved and extracted; and that then, in the mechanical treatment of it, the woody parts may be readily and perfectly ſeparable from it, and the bark divided into its minuteſt fibres. In this operation, however, a kind of putrefaction muſt inevitably in ſome meaſure take place in the mucilaginous part; and therefore great care ſhould be taken that the fibres themſelves be not acted upon, and rendered too ſoft and tender.

In order to bring *Flax* to the utmoſt degree of *fineneſs* the fibres of its inner bark muſt be divided as minutely as poſſible; but as this, for fear of a putrefaction taking place, that may prove detrimental, cannot be obtained by the uſual method of maceration in water, it muſt be effected in another way. This intention is accompliſhed by boiling the flax, which has been already prepared in the uſual way, in a ſtrong ley rendered cauſtic by lime. By this means the mucilaginous and gummy parts ſtill contained in it, which are, in fact, what prevent the ultimate diviſion of its ſmalleſt fibres, is extracted, without theſe fibres being expoſed to the leaſt damage. By this method it actually acquires a great degree of fineneſs, and at the ſame time becomes as white as if it had been half-bleached. Laſtly, when it is once more hatchelled, the hards are obtained ſo fine, that, after ſome preparation, they may be made almoſt to equal cotton.

The ſame proceſs is followed in the preparation of *hemp*, the larger *ſtinging nettle*, *hop-binds*, and ſeveral other fibrous vegetables, as alſo with the coarſer barks of ſoft wood, with a view to obtain the *baſt* or *inner bark*.

At length, when the flax, after having been uſed to the utmoſt, is worn out, it is degraded again to the ſtate of *rags*. But ſoon after a freſh improvement and exaltation takes place in it. Theſe rags being bought up by the paper-makers, and by them ſorted into parcels, then cut to pieces, maſhed together, all the interwoven threads entirely unravelled again, and brought anew into their priſtine downy ſtate, though now, much finer than before; and, in fine, converted into *paper*, which, that it may be the more durable, is paſſed through thin ſize mixed with alum.

Prior to this great invention, the ancients, in order to record certain facts and events, employed ſtones, lead, bronze, tiles, ſlate, wood, leaves, the inner

bark of trees or baſt, linen, the ſkins and inteſtines of animals, wooden boards covered with wax, and ivory. The Egyptians laid the firſt foundation of the manufacture of paper, by employing the inner rind of the ſtalk of the papyrus, or paper plant. But *Ptolemy* king of Egypt having prohibited the exportation of this paper to foreign countries, it induced the people of Pergamus to prepare in an approved ſtile the ſkins of animals, which had been uſed for a lon time before; and by this means, about 300 years before the birth of Chriſt, they invented the ſubſtance called *parchment*, in Latin *Pergamentum*, which ſtill bears that name, but which was not uſed in Europe before the 6th century. A ſhort time after this, the Egyptian paper was totally neglected on account of the more general uſe of parchment, as well as in conſequence of the *invention of cotton paper*, which was diſcovered about the 8th or 9th century. The Arabians t-tribute this diſcovery to one *Joſeph Amru* in the year 706, though it is ſaid that the Perſians and the Chineſe knew it before. The paper at preſent in uſe among the Perſians is made of cotton and linen, which they paſs through glue made of rice, though they alſo make another kind of ſilken rags, which they whiten with ſoap, and poliſh with glaſs. The Chineſe have ſince the firſt century of the Chriſtian æra made their paper of the interior bark of the bamboo; they alſo uſe the pods of the ſilk-worm after the ſilk has been wound off, and likewiſe the tender membrane of the Kuchu tree. The inhabitants of Thibet make their paper of the roots of a tree, which reſembles tow, or the hards of flax. This they ſuffer to putrify in water, and then beat it to the conſiſtence of pap, which they employ for making paper. The Japaneſe make this uſeful article of the *morus papyrifera*, which abounds in that country, and is a ſpecies of mulberry tree, of an aſtoniſhingly quick growth. Having cut off the young twigs, they ſteep them for the ſpace of twenty-four hours in cold water, and then boil them in a ley of wood-aſhes. After they are become cold, they ſcrape off the outer bark; and, ſplitting them lengthways, take off the bark, with which the paper is made. Theſe latter ſorts of paper, however, never came into general uſe; except the cotton paper, which was uſed in Europe till the 14th century, and for which great ſums were ſent yearly to Aſia.

Theſe circumſtances probably induced the Germans to make paper in the ſame manner, as had been done with cotton in the Eaſt, and their endeavours were attended with ſucceſs. The firſt paper was made of cotton and woollen rags mixed together; as in thoſe times more cotton was worn than linen. At length the increaſed

increaſed cultivation of flax diminiſhed the importation of cotton, and produced a ſufficiency of materials, for making paper ſolely of linen. It is aſſerted that the moſt ancient memorial of this event is to be found at Amſterdam, of ſo early a date as in the year 1322. It was in Italy and Spain that cotton paper continued in uſe the longeſt. According to M. *van Murr*, pretty good linen-paper was made ſo early as in the year 1319. At all events it ſeems probable that the diſcovery was made about this time, and that by the Germans.

Beſides linen rags, M. *Schaefer* at Ratiſbon, has actually made paper of moſs, the downy ſeeds of the poplar, hop-binds, the bark of the willow, tow, of the wood of the mulberry-tree, of ſtraw, of the leaves of the aloe, of the ſtalk of the turnep-rooted cabbage, of the traveller's joy, and of the common large nettle. Undoubtedly many more vegetables might be found likewiſe fit for this purpoſe, amongſt which may be reckoned all thoſe that become woolly when rubbed, and all barks and roots which are compoſed of tender fibres, and are to be had in great quantity.

Finally, we muſt not omit to mention in this place, the diſcovery of Profeſſor *Claproth* of Gottingen, that all old and waſte printed paper may be again rendered fit for uſe: for doing which the chief point conſiſts in beating up the paper after it has been ſteeped, with a little lime, fuller's earth and water, in order to diſſolve the ink, and waſh it out. After which a tolerably ſerviceable printing paper may be obtained from the remaining materials *.

In the *Culture of Meadows* there is no uſe for the plough; and indeed there is likewiſe ſeldom any alteration requiſite with reſpect to the compoſition of the ſoil. As likewiſe the land that has been appropriated to meadows, generally lies rather low, and is ſometimes overflowed by water, no further manuring is neceſſary. They are more liable to be hurt by another circumſtance, that they are apt to grow too moiſt, and become moſſy. The former inconvenience may be removed by interſecting the meadows with ſmall trenches, and the latter by ſtrewing over them ſome ſtraw-aſhes, or the elixated earth of the ſoap-boilers. In default of the natural, artificial meadows are laid down, by ſowing various kinds of herbs fit for foddering cattle, ſuch as rye-graſs, ſaintfoin, and the different kinds of trefoil.

* The way to make freſh paper out of paper already printed, by Dr. *Juſt. Claproth*, Gottingen 1774. 8vo. [A]

The object of *Gardening* is the cultivation of smaller pieces of land, with a view of producing flowers, fruit and other useful garden-plants. As all this is an object of mere curiosity and pleasure, more trouble and expence may be bestowed upon it, and also more may be accomplished in this sort of culture. For the pitch to which art has arrived in the culture of gardens, is really a subject of wonder and admiration.

Here no difficulties of any kind occur in first giving the soil its proper composition. It may be dug up more frequently and deeper, mixed with sand or with any other kind of earth that is required; cleared from stones, and roots of weeds, by means of screens and riddles, and meliorated according to all the rules above-mentioned. Likewise, on account of the greater value of the vegetables, manure of the best kind may be employed here, and that in the greatest abundance.

It is also, on account of this frequent turning and copious manuring of the soil, that garden ground may be used every year.

In the *cultivation of flowers* it is a general maxim, that all parts that originate from animals and vegetables, of which the manure consists, must necessarily be previously reduced from their hitherto determined nature to an indeterminate state, and to a substance of extensive and general application, that is, they must be reduced to earth, before they can serve as nourishment to the tender flower-plants. All these parts therefore must be first entirely and completly dissolved. The way to effect this, is by putrefaction, which continues till the solution has entirely taken place. Therefore, when dung that is not yet perfectly rotten and converted to earth, is laid to the roots and plants of flowers, the putrefaction that is commenced will continue till the dung is completely rotted. But as, agreeably to the occurrence of every attentive gardener, neither seeds nor flower-plants can bear an earth, that is still in a state of putrefaction; since they are also liable to be attacked by this same putrefaction, and grow weakly from it, and frequently perish; the reason is very evident why it is requisite that the dung should be completely converted into earth by putrefaction before it can be applied to this kind of seeds and plants. Hence every prudent gardener suffers the dung that he designs for soil for flowers to lie by for several years, till it is totally converted into earth. In this very circumstance also consists the superiority of an earth composed of leaves and wood, which must not have the least putrid, offensive smell, but on the contrary, a rather agreeable odour.

To

To make a good *earth for clove July flowers*, equal part of good rotten earth from cow-dung, good garden-mould, and river-ſand may be mixed together.

When exotic vegetables are to be cultivated, the quality of their natural ſoil ſhould be enquired after, whether it be ſandy, looſe, or heavy, dry or moiſt, and attempts made to imitate it by an artificial mixture. Beſides this, care ſhould be taken to procure for them by art their natural climate, in which they have been reared.

Their native ſoil may be imitated upon the principles above-mentioned. The nutritious particles are, in a proportionate quantity, produced by the addition of mould, conſiſting of leaves, wood, or dung, properly rotted, and the requiſite temperature of moiſture is effected by means of good water.

Though care ſhould be taken in the watering of plants growing in pots and tubs, that the whole of the earth contained in the latter be moiſtened, and that theſe veſſels ſhould have holes in their bottoms, by which the redundant water may run off, and not become corrupt and putrid, by being intercepted; yet it is neceſſary on account of this very circumſtance, to confine the watering within ſuch limits that too great a quantity of the redundant water may not paſs through; becauſe every particle of water that thus runs off, will certainly alſo carry off a portion of the good and ſoluble nutritious particles of the earth. A ſkilful gardener will water his plants in ſuch a manner, that but little water ſhall run out of the pots and tubs; and will rather repeat the watering the oftener in ſuch plants, as from their nature they may require much moiſture.

Common river-water is always beſt for this uſe, as well as the moſt natural. Saline particles are for the moſt part prejudicial; they ſeem to occaſion a greater quantity of earthy particles to be diſſolved by the water and introduced into the plants, in conſequence of which probably, in the ſequel, indurations and obſtructions will enſue in their minute and tender veſſels. This conſideration too may ſerve to explain the common obſervation, that vegetables do not thrive ſo well with hard waters as with the ſofter river- and rain-waters. Hard waters however may be meliorated by expoſing them to the air and ſun, and mixing them with a little dung or aſhes, a ſeparation of the earthy particles being effected by means of the alkaline ſalts. Such vegetables as by their nature are diſpoſed to grow in a ſalt ſoil, may alſo be watered with water ſlightly ſalted; in other reſpects ſalt and urine are always of more detriment than ſervice.

For the production of an *artificial climate*, and for the purpose of supporting and raising such vegetables, as are indigenous in hot countries, and also of accelerating the growth and procuring more early blossoms and fruits in our indigenous plants, *hot-houses* are constructed, in which plants of this kind are secured from the sharp and cold winds, and the air within made of a proper degree of warmth, either by the rays of the sun or by a gentle fire. As also *hot-beds* are contrived in them, consisting of horse-dung, tanners-ouse, saw-dust, and other substances of an incalescent nature, in which the tubs and pots are placed. Smaller and single plants may likewise with this view be covered with glass bells. In all these cases however it must not be forgotten to procure for the plants sun and a draught of air. Hither may also be referred the artificial method of producing various kinds of flowers in the winter season.

The singular art practised by gardeners, of producing *double flowers* from *single* ones depends on this; the stalk of every flower consists of five different substances, one of which always regularly environs and incloses the other. These are, 1. the exterior bark; 2. the interior bark; 3. a series of vessels; 4. the parenchymatous substance; and, 5. the pith. The roots consist of the very same materials. The substances abovementioned originate in the roots, and are continued on to the end of the stalk; where, in fine, the different parts of the flower are formed by them. All parts of flowers are continuations of the one or the other of these substances; the duplication of a flower therefore must arise from a redundant luxuriance of one of these parts. Now, when a flower is intended to be made fuller, it should be considered which of the essential parts of a plant is fittest for this luxuriant vegetation, to which of the above-mentioned five substances such a part belongs, and, lastly, by what kind of nourishment and culture its growth may be best promoted.

Upon the very same principles the double flowers may be formed moreover to become *proliferous*, of which there are instances in the ranunculi, anemones, auriculas, roses, pionies, monardas, &c. With this view, the following maxims are chiefly to be observed. Of the five substances, of which a perfect plant consists, only two contribute to the proliferation. These are the bast, and the fleshy substance, being the third and fourth part of the plant, reckoning from its surface. The fleshy part has the first of the chives, which when they receive redundant food, form petals, and cause the doubleness, but the bast, on the other hand, in consequence of a redundancy of nourishment, rises up above the flowers like a stalk, and occasions the proliferation.

The

The luxuriance of the flefhy fubftance arifes from the redundancy of a particular fpecies of alimentary matter; and the luxuriant growth of the inner bark is alfo derived from the fame caufe. But the increafe of an univerfal nourifhment, of which all the parts equally partake, equally enlarges the whole plant.

But according to the moft authentic obfervations, there are feveral different kinds of foil which promote the luxuriant growth only of certain parts of a plant. This power proceeds from certain peculiar particles contained in them. Now, with refpect to thefe, Dr. *Hill* has obferved, that the marle promotes the growth of the woody part in trees, or augments the flefhy part in the tender plants; but that a deeper vegetable foil increafes the baft or inner bark. When the former of thefe parts of a plant has been brought to an increafed growth, the doublenefs of the flower is produced; and when this increafe has taken place in the fecond, it becomes proliferous *.

Finally, in the *keeping of feeds*, care muft be taken that the vegetative power be not deftroyed in them. They are fubject to this evil, partly in confequence of too great exficcation, partly for want of air, partly from a redundancy of moifture, by which an incipient putrefaction is occafioned, and partly by infects. Good ripe feeds therefore muft be fpread out in a moderately warm place, and dried gently; and then are beft fufpended free in linen bags in a dry air, by which means they are fecured from all damage. Seeds that grow in pods are beft kept in this their natural cover and defence. The feeds of exotics fhould be covered with wax, in order that they may not be damaged during the voyage.

The chief occupation of *rural œconomy* confifts in the rearing of cattle or *grazing*, in which the cultivated vegetables are employed with a view to greater profit. In this branch of hufbandry, refpect muft be had to the feeding, the attendance, and the profit that may be made of them.

The fodder that a hufbandman gives his cattle muft be confidered by him as a capital that he puts out to intereft. A fmall fum produces but a flender income, and with bad fodder it is impoffible for cattle to yield large profits; even their dung will in this cafe be found to be of inferior efficacy. The moft profitable product obtained from cattle confifts in their milk, of which are made

* A circumftantial detail of this procefs may be found in Dr. *Hill's* Treatife on the Origin and Generation of proliferous Flowers, &c. [A]

butter and cheeſe; ſubſtances of which the goodneſs conſiſts in their oily particles. But who can believe that this does not come originally from the food of the cattle, and that they will produce the ſame quantity of it, with good as well as with bad fodder? This queſtion anſwers itſelf.

No ſour vegetables ſhould be offered to cattle that give milk. They loſe their milk by it; and then perhaps the evil is attributed to witchcraft. Under this head may be ranked the reedy graſs which grows in marſhy meadows, &c The beſt remedy for this imaginary enchantment is good nouriſhing fodder, conſiſting of ground beans, oats, peaſe, or lentils given warm to the cattle, together with a powder compoſed of mucilaginous emollient herbs and ſome aromatic ſubſtances, mixed with wood-aſhes and common ſalt, which they muſt be made to take for ſome time.

The contrary of this circumſtance ſometimes occurs in milk, viz. that in the churning of butter, this latter will not ſeparate from the cream. This inconvenience may be remedied by pouring a little vinegar along with the cream into the churn. There is yet another defect in milk, in conſequence of which it yields a very blue cream. By way of elucidating this circumſtance, I ſhall mention thus much, that the chyle, ariſing in animal bodies from the diſſolved nutritious particles, is gradually changed into blood in ſuch bodies as yield no milk; but when, on the contrary, theſe animals give milk and ſuckle, this fluid, together with the blood, is carried into the enlarged glandular veſſels of the breaſts or udder, during the time above-mentioned, there ſeparated from the blood, and depoſited in the form of milk. Conſequently the milk originally conſiſts of the chyle, which for ſome time has been ſlightly mixed with the blood, and ſeparated again from it. Now, when in this laſt period the ſecretory veſſels have been diſtended ſomewhat more than they ought to be, ſome of the red globules of the blood paſs over into the milk, and occaſion the change of colour, which the ſuperſtitious vulgar has for a long time conſidered as the conſequence of ſorcery and inchantment, and ſtill continues to do in ſome places. The whole of the cure may be performed by natural means, viz. by ſtrengthening and aſtringent remedies.

With regard to the reſt of the treatment of and attendance upon cattle, it muſt be obſerved, that they muſt be duly fed at regular times, and have their drink warm in cold weather. In the ſpring and autumn they ought not be driven too early to field, nor too late home. The perſpiration of the cattle

ought

ought alſo to be promoted by rubbing them with coarſe cloths or with a curry-comb. As to what relates to their diſtempers, it does not belong to this work, but rather to the veterinarian art.

For the *fattening* of cattle indeed all ſorts of fodder may be uſed, and which ſometimes cannot be put to any other uſe. Thus the reſiduary grains of the diſtillers and ſtarch-makers, and the impure fig-meal of the millers, or cleaning of the mills, are uſed for this purpoſe. Here again, however, this maxim holds good, that the beſt fodder fattens beſt. The cattle muſt be fed often, but with moderation; in particular their food muſt be warm, and they muſt have reſt. A difference in the fodder produces alſo a great difference in the fat that is generated; as this is not always equally ſolid from every kind of food; of which again the cauſe is to be looked for in the nature and elementary compoſition of the fodder.

BOOK

# BOOK III.

## PHILOSOPHICAL CHEMISTRY*.

## CHAP. I.

### DEFINITION OF PHILOSOPHICAL CHEMISTRY AND PHYSICAL ELEMENTS.

NATURAL *Knowledge* is the knowledge of the properties of bodies, of the changes produced in thoſe properties, and of the cauſes by which both the properties and the changes that take place in them are produced. It is divided into two branches.

I. *Natural Hiſtory*, which is the knowledge of the properties of bodies, and of the changes produced in thoſe properties.

II. *Natural Philoſophy*, or *Phyſics*, which is the knowledge of the cauſes, as well of the properties of bodies, as of the changes that take place in thoſe properties †.

*Philoſophical Chemiſtry* therefore (Chemia Phyſica) is the application of Chemiſtry to the explication of theſe cauſes.

According

* Here the Reader, in conſequence of the diviſion of the different departments of Chemiſtry made at page 141, may naturally expect to find *Pharmaceutical Chemiſtry:* but what the author has advanced upon the ſubject in this place being rather applicable to the mechanical than the chemical part of Pharmacy, for which latter the ſtudent is chiefly referred by him to the ſeveral obſervations and remarks ſcattered up and down in the Halurgy, Phlogurgy and Metallurgy, we have thought proper to omit the mention of it altogether, eſpecially as the excellent Treatiſes of *Lewis* and *Beaumé* on this ſubject are in every one's hand. [E]

† But theſe changes are produced by the mutual action of the bodies, or of their parts upon each other.—And human induſtry can do nothing more towards producing theſe changes than merely to place the bodies in a favourable ſituation for acting upon each other, and to communicate motion to them, where it is wanting. [E]

Natural

According to the laws of good method, it is neceſſary to conſider firſt the ſimple, and then proceed to compound ideas: in a treatiſe on Philoſophical Chemiſtry therefore, it will be proper to begin with the Phyſical Elements, and then proceed to the ſubſtances compounded of theſe.

The ſubſtances generally, but improperly, ſtiled Phyſical Elements*, are *Fire, Air, Water* and *Earth*. Of Fire and Water we ſhall treat at ſome length in this place; referring the Reader for the other two to the Introduction to this Treatiſe.

Natural Philoſophy therefore is diviſible into two principal branches, *Mechanics*, and *Chemiſtry*; for the definition of which vide page 1.

In general, in the art of *Chemiſtry*, the *former* of the abovementioned conditions merely is requiſite; in *Mechanics*, both. [E]

* Theſe are called Phyſical Elements merely from a blind deference to the authority of the ancients, who, except the Egyptians, do not appear to have had any knowledge of Chemiſtry, at leaſt as a Science. They might be more properly termed *Univerſals*, as they are diffuſed all over nature, which was probably what induced the ancients to ſuppoſe them to be the moſt ſimple bodies, and the *elements* or *principles*, of which all other bodies were compoſed. The true Phyſical elements are evidently the Chemical and no other. [E]

CHAP.

# CHAP II.

## Phosphori.

FIRE is divifible into *Light* and *Heat*, which are two real chemical and, therefore phyfical, elements quite diftinct from each other, of which the idea of fire is compofed. Light firft offers itfelf to our confideration.

There are fome bodies that attract the light, and give it out again immediately afterwards in any temperature of the air, on being carried into a dark place. Thefe are ufually called Phofphorefcent Subftances. The Germans more aptly term them *Magnets for light* (Licht magnete).

Other bodies, in which the light is fixed in the form of phlogifton, give it out only in certain degrees of heat, and in confequence of being expofed to the air. They differ from other bodies only in the low degree of heat at which they give out their light, and in yielding much more light than heat, in comparifon with other fubftances. Thefe are properly termed Phofphori, or *bearers of light*.

Each of thefe Claffes of Bodies may be diftinguifhed into *natural* and *artificial*.

At the head of the *naturally phofphorefcent bodies* may be placed the Diamond. But *Beccaria* found that there were few fubftances that did not poffefs more or lefs of this property, and that it was particularly exhibited by white paper.

At the head of the *artificial phofphorefcents* is Bolognian Phofphorus, (as it is fometimes improperly called) or prepared Bolognian ftone.

Next to this are the Phofphori, as they are termed, of *Canton* and *Balduin*.

The bafis of the firft is barytes, or heavy earth, and of the two laft calcareous earth.

The *Bolognian Phofphorus* is, as it were, the origin and head of the whole family of Phofphorefcents. The firft difcoverer of it was a fhoemaker, called *Vincenzo Cafciarolo*, who applied himfelf to alchemiftry. This man, in the year 1604,

walking at the foot of Mount Paterno, found ſome ſtones, the great weight and luſtre of which induced him to believe that they contained ſilver. But having calcined them in the fire, he got neither gold nor ſilver out of them, but diſcovered in them the luminous property abovementioned.

As moſt inventions are imperfect at the firſt outſet, ſo it happened in this caſe likewiſe. The antient mode of preparing this ſtone may be ſeen in *Lemeri's* works. But it has been improved by *Marggraf*, and is deſcribed by him as follows: Such of theſe ſtones are to be ſelected for the operation, as are moſt heavy, moſt friable, and exfoliate when broken. Theſe are to be made red-hot in a crucible, and reduced to a very fine powder in a ſtone-or glaſs-mortar; but, on no account whatever in a braſs one. This powder is then to be formed into a paſte with mucilage of gum tragacanth, and divided into cakes as thin as the back part of a knife. Theſe are to be dried at firſt with a gentle, and at laſt with a conſiderable heat. After theſe preparations, a wind-furnace is to be filled to three fourths of its height with pieces of charcoal of the ſize of walnuts, and the fire is to be kindled. Upon this charcoal the flat ſurfaces of the cakes are to reſt; and more charcoal is to be placed above them, ſo as to fill the furnace. All the coal is to be conſumed, and the furnace left to cool. The cakes are then calcined, and are to be cleanſed from the aſhes by blowing upon them with the bellows. It is abſolutely neceſſary that theſe ſtones be not calcined in a crucible, but in the open fire.

The Bolognian Stone thus calcined is now remarkably altered; it has loſt its former colour, being now of a variegated hue; it ſmells of ſulphur, and, immediately after being expoſed to the day-light, ſhines, upon being carried into a dark place, like an ignited coal.

*Marggraf* alſo mentions in his chemical writings ſome ſorts of ſtones found in Germany, which have properties exactly ſimilar to thoſe of the Bolognian Stone. From his analyſis it appears, that all theſe ſtones conſiſt of calcareous earth combined with vitriolic acid; conſequently they were found to be of a gypſeous kind. Theſe experiments paved the way for him to attain to the knowledge of the *Conſtituent parts of the Bolognian Stone.* Indeed, he at laſt proceeded ſo far, as to make artificial ſtones, that poſſeſſed in like manner the faculty of ſhining *.

He

* M. *Marggraf* approached only ſo near to the knowledge of the Conſtituent parts of the Bolognian Stone, as to diſcover in it vitriolic acid, and an earth reſembling calcareous earth. He was

He ſet about this artificial imitation in the following manner: He diſſolved ſome lime-ſtones from Riederſdorf in the nitrous acid, by putting ſmall pieces of theſe ſtones into the acid, as long as he ſaw that any part of them was diſſolved. The ſolution was diluted with four parts of water, precipitated with vitriolic acid, and the precipitate well edulcorated with water. When this, after being dried, is a little calcined, made up into a maſs with mucilage of gum tragacanth, and then calcined again with charcoal, in the manner deſcribed above; a ſubſtance is obtained, that ſtrongly attracts the light. The ſame reſult is obſerved to take place, when the fixed ammoniac, as it is called, which is nothing elſe than a calcareous earth united with marine acid, is precipitated with vitriolic acid. In this manner M. *Marggraf* proceeded with a variety of ſubſtances, and in theſe operations obſerved the following changes with regard to colour and light.

The Selenitic ſubſtance from the Riederſdorf lime-ſtone, by calcination with charcoal, yielded a *white light*. The Selenite obtained from the ſolution of fixed ammoniac, produced a *reddiſh light*. Chalk diſſolved in nitrous acid and precipitated with vitriolic acid, gave a *white light*. Carlſbad Stone diſſolved in nitrous acid and precipitated with vitriolic acid, yielded a *pale light*, ſomewhat verging towards *red*. Oyſter-and cockle-ſhells diſſolved in the nitrous and precipitated with the vitriolic acid, after the abovementioned treatment, ſhone with a *red light*. Marble diſſolved in nitrous acid, when precipitated in the aforeſaid manner with vitriolic acid, and calcined, afforded a *white light*. The Stalactite from the *Workman's cave* exhibited a ſimilar *white light*, when treated in a ſimilar manner.

The natural Bolognian Stones as well as thoſe produced by art, in proceſs of time loſe their power of attracting light, in caſe the air can get acceſs to them. Hence they muſt be carefully kept from it, which is beſt done in hermetically ſealed glaſſes. The moſt convenient veſſels for this purpoſe are white glaſs tubes, which are firſt hermetically cloſed at one end, then filled with the luminous ſtones broken into ſmall pieces, upon which the tube muſt immediately be cloſed

was however miſtaken in ſuppoſing this earth to be calcareous. The Bolognian Stone is a ponderous ſpar, and its earthy baſis terra ponderoſa, the peculiar nature of which was not known at that time This error was the more likely to take place, as calcareous earth likewiſe under the ſame circumſtances acquires the ſame property. Hence with reſpect to the artificial imitation of it, he was not fruſtrated in his purpoſe. [A]

alſo

also at the top. In this operation, care however must be taken that none of the powder of these stones enter into the glass; the tubes filled in this manner, ought likewise not to be shaken; otherwise, if there should happen to be any powder in them, it would adhere to the glass, and obstruct the passage of the rays of light.

All these masses have a sulphureous smell after calcination, and then likewise in part dissolve in water. For, as they consist of calcareous earth combined with vitriolic acid, it follows, that when they are calcined in immediate contact with the coals, their phlogiston combining with the vitriolic acid, forms a true sulphur; and the calcareous earth at the same time is, during the calcination, converted into quicklime, with which the newly generated sulphur forms an earthy liver of sulphur, the same as when sulphur and quicklime are mixed together and fused. Now in this combination the sulphur dissolves in water together with part of the lime.

This position is likewise proved by *Canton's phosphorus*, which is prepared by calcination from a mixture of calcareous earth with sulphur. As this preparation requires the purest calcareous earth that can be procured, it is usual to employ for this purpose oyster-shells which are well boiled and carefully cleansed from all impurities. They are then calcined in a crucible, till they become quite friable, in order that they may be triturated to powder in a glass-or stone-mortar. Afterwards this powder being mixed with equal parts, or sometimes with only half the quantity of sulphur, is pressed down close in the crucible, and a second time urged with a red heat, for the space of an hour. In this operation the particles of the powder cleave together, so that the phosphorus is obtained in one piece, which by a stroke may be divided into small pieces; the upper stratum is commonly found to be of rather a lighter colour than the rest; this must be taken off with a knife as far as it is observed to reach, and the whitest part only must be saved, for this alone shines when it has lain for some time exposed to the light. Care must be taken in this operation not to pound the crude oyster-shells in a metal mortar; as in this case they will not acquire the luminous property. When these sorts have lost their faculty of attracting the light, it may be restored to them by a fresh calcination. It is moreover a remarkable circumstance in this phosphorus that, as has been observed by *John Baptist Beccaria* of Turin, it will yield a light of any colour, according to the colour of the ray of light to which

it has been expofed. For this purpofe it is covered with a red, green, or blue glafs*.

*Balduin's Phofphorus* likewife is of the number of the phofphorefcent fubftances, or *Light-magnets*. It was difcovered by an accident to which an alchemiftical whim had given rife. *Balduin* was a juftice of peace at Groffenhayn in Saxony, who, for the attainment of his fublime views, endeavoured to catch the univerfal mundane fpirit, for which purpofe he performed various and numberlefs operations, which all proved unfuccefsful. In fome of thefe operations, however, he obferved, that a certain mafs that remained behind at the end of his experiment fhone in the dark, when it had been previoufly expofed to the daylight. To this he gave the name of *Phofphorus hermeticus*, or *Magnes luminaris* †. To prepare this, as much chalk is diffolved in half a pound or a whole pound of aqua fortis as this will take up, the folution is filtered, and evaporated to drynefs in a glafs capfule, or faucer. The dry mafs is afterwards urged with a red heat, in a fhallow unglazed veffel of earthen ware, over a moderate fire, in confequence of which, at firft, it expands and fwells up. As foon as it has fubfided, and the whole is become thoroughly red-hot, the veffel is taken from the fire. Round about the earthy mafs that lies in the middle of it, a yellowifh border is found, which poffeffes the property abovementioned.

The real caufe of the power of attracting light in the beforementioned kinds of phofphorus, no one has ever yet been able to explain in a fatisfactory manner. It fhould feem indeed that the ftate of privation of air, into which the ponderous or calcareous earth is put, by being treated in fire with the fubftances that are added to it, muft make it fit to attract the light ab extra; the added fubftances however muft neceffarily contribute fomething to this, as pure calcareous earth deprived of air does not poffefs this property‡. In Balduin's phofphorus it is a

* This experiment was likewife made, with fome variations, above twenty years ago, by Profeffor *Allamand* of Leyden; but it has been fince repeated by Mr. *Wilfon* and others without fuccefs. [E]

† Chrift. Ad. Balduini aurum fuperius et inferius, auræ fuperioris & inferioris hermeticum, et phofphorus hermeticus feu Magnes luminaris. Francof. & Lipfiæ, 1675, 12mo. [A]

‡ On the contrary, it is probable, that it is by being impregnated with air that thefe fubftances acquire the faculty here fpoken of; or at leaft that this circumftance contributes greatly to their acquiring this faculty. It muft be obferved, however, that the author in this paffage does not mean pure air, but fixed air, or, what is more properly, termed the aerial acid. [E]

particularly

particularly remarkable circumſtance, that the greateſt part of the calcareous earth which remains in the middle, impregnated with nitrous acid, does not acquire the property of attracting light, but that only a ſmall quantity which adheres round it, is poſſeſſed of the luminous property. It is probably phlogiſton that renders the de-aerated calcareous earth fit to attract the light with certain degrees of affinity.

We now come to the Phoſphori, properly ſo called. Theſe may be alſo divided into *natural* and *artificial*. The former abound in different parts of the animal creation. Of theſe, the *Glow-worm* or Lampyris noctiluca, is the beſt known to us*. Beſides this, there are ſeveral ſorts of Elaters; as the *Cocujo* or Elater noctilucus, and the Elater phoſphorcus, likewiſe the *Fulgora* of Linnæus, and the *Sea-Pen* (Pennatula phoſphorea) which have a claim to this title. To theſe may be added a great variety of worms inhabiting the ſea; the Nereis noctiluca L. ſeveral ſpecies of the *Meduſa*, the *Pholas dactylus* L. &c. Various bodies, when in a ſtate of putrefaction, ſuch as veal, ſome ſorts of ſea-fiſh, and likewiſe wood, are inſtances of natural phoſphori, which will in ſome meaſure ſerve to account for the reſt. The two former ſubſtances, indeed, are well known to contain the phoſphoric acid.

With reſpect to genuine *artificial Phoſphori*, there is but one ſpecies known at preſent, viz. the *Phoſphorus of Urine*. This is a yellowiſh inflammable ſubſtance, hard in the cold, and fuſible in a moderate degree of heat, which, expoſed to the open air, yields a luminous vapour, that is at any time perceptible in the dark, and emits a very diſagreeable odour of garlic. The matter of light is one of its conſtituent parts, and has its ſource in the phoſphorus itſelf. It is therefore, as its name imports, a real *luciferous body*, which ſhines with its own light.

It was diſcovered by accident in the year 1669, by a bankrupt merchant at Hamburg of the name of *Brand*, who ſought to make his fortune by alchemiſtry, and attempted to procure the Philoſopher's Stone, as it is called, but which might with greater propriety be called the Idiot's Stone. He kept the

* The fluid ſecreted upon the external ſurface of the body of this inſect ſeems to be in a continual ſtate of decompoſition: by which means light is produced. This is confirmed by a fine experiment made by the younger *Foſter*, and publiſhed about two years ago in the Gottingen Magazine. He incloſed ſome of theſe animals under a glaſs, into which dephlogiſticated air was admitted, when theſe animals gave out a much more vivid light than before. [E]

prepara-

preparation very ſecret in the beginning; but it was not long before *Kunkel*, who lived at the ſame time, and had learned that *Brand* had been ſeeking to make his fortune by means of urine, likewiſe diſcovered it. As both laid claim to the invention, this product has ſince preſerved the name as well of *Brand's* as of *Kunkel's phoſphorus*. It is made merely of putrefied urine, which is evaporated to total dryneſs, mixed with two parts of ſand and one of powdered charcoal, and diſtilled in a ſtone-ware retort, with a briſk fire. According to *Marggraf's* preſcription, ten pounds of urine, evaporated till it is become quite thick, are mixed in an iron kettle, with three pounds of plumbum corneum, and half a pound of powdered charcoal, and dried up, being all the time continually ſtirred, to a perfectly black powder. The whole of this powder is then put into a glaſs retort, and from thence as much as can be obtained of it is drawn off by diſtillation, till the retort is of an obſcure red heat. The friable carbonaceous reſiduum is rubbed fine, and diſtributed into ſix ſmall ſtone-ware retorts, coated with loam, which are put all together into a furnace proper for the purpoſe, to be diſtilled. This diviſion is made with the intent, that if unfortunately one of the retorts ſhould happen to burſt, the whole maſs may not be loſt at once, as it is not to be likely that they ſhould all break. Theſe ſmaller veſſels are beſides better penetrated by the fire, than one great retort that would be capable of containing the whole maſs. But as the phoſphorus obtained by this operation is generally ſtill impure, it ought to be diſtilled once more from a glaſs retort into a receiver containing ſome water, and by this means purified. Finally, by way of giving it a convenient form, it muſt be made into longiſh cylindrical ſticks, in the following manner. A glaſs tube muſt be procured of an equal diameter throughout, and about the thickneſs of a ſmall quill, but ſhaped like a funnel at top. The tube of the head of a ſmall alembic may alſo be uſed for this purpoſe, provided its interior ſurface be perfectly round and ſmooth. The lower aperture muſt be cloſed with a cork. The phoſphorus is then put into the tube in ſmall pieces, where it immediately melts by the heat of the water, ſinks to the bottom of it, and runs together in the lower and ſmaller part of the tube. Upon this the tube is transferred from the warm into cold water, in conſequence of which, the melted phoſphorus immediately grows hard. When it is quite cold, the upper part of the tube is turned downwards, put into a diſh full of cold water, the cork taken out from the narrow end, and the phoſphorus, which is now hard, puſhed up out of the tube from beneath

into the cold water, by means of an iron wire. When the phoſphorus muſt be broken into ſmall ſticks of the ſize that is wiſhed for, and kept in glaſſes, which muſt be filled with water quite up to the top. From the above quantity M. *Marggraf* obtained two ounces and a half of pure phoſphorus.

There is another mode of preparing phoſphorus, that ranks among the lateſt diſcoveries. In conſequence of its having been found, that animal earth conſiſted of calcareous earth, which was moſtly ſaturated with animal acid, attempts were ſoon made to apply this diſcovery to ſome uſe. Dr. *Henry Gahn* of Stockholm, was the firſt that informed the public in what manner phoſphorus may be obtained from the bones of animals *. For this purpoſe as much burned hartſhorn reduced to a coarſe powder is diſſolved by means of heat in aqua fortis or ſpirit of ſalts, as theſe acids are capable of taking up. The ſolution, after being filtered, is diluted with three times its quantity of water, and mixed with vitriolic acid, till no farther precipitation enſues. This precipitate conſiſts of ſelenite, and muſt be ſeparated by filtration. The clear liquor conſiſts of the nitrous and phoſphoric acids, and may be evaporated in an open bowl, till the odour of the nitrous acid is perceived, upon which the whole is put into a retort and all the liquor diſtilled from it. The dry maſs remaining in the retort is diſſolved in water by means of heat, and filtered †. This liquor, in caſe that it is to be made into phoſphorus, muſt be evaporated to the conſiſtence of

* Though Dr. *Gahn* was the firſt that communicated this method to the public, yet *Scheele*, and not he, is the real inventor of it. [A]

† Another method of procuring the phoſphoric acid from bones has been propoſed in No. 7, page 385, of a late periodical publication, intitled, *the Repoſitory*. It is as follows:——Calcine bones till they are quite white; mix three parts of this earth with two of ſtrong vitriolic acid, and let the mixture remain quiet for ſome days; then add water to it, filter and evaporate the liquor, till the ſpecific gravity of it becomes to that of rain-water, as 126 to 100. After this pour into it aerated volatile alkali (aerocratic ammoniac) by little and little, which will entirely ſeparate the earthy part from it. The liquor is next to be filtered, in order to extract all the ſaline part, and diſtilled water muſt be poured upon the matter that remains in the filtering paper. The liquor is then to be evaporated, and when the fluid part is almoſt evaporated, the fire muſt be increaſed, by which means the volatile alkali is expelled, and the phoſphoric acid vitrifies in the form of a pure glaſs.

The purified phoſphoric acid, adds this anonymous author, cryſtallizes very eaſily, under the form of quadrangular priſms, which are terminated by quadrangular pyramids. [E]

honey,

honey, and mixed with as much powdered charcoal, as will again convert it into almoſt a dry maſs. This is then put into a glaſs retort coated with clay; and the phoſphorus diſtilled over with an open fire into a receiver filled with water *.

The moſt advantageous mode of preparing *phoſphorus* is that deſcribed by M. *Niclas*. I have tried it, and found it to anſwer; having proceeded in the following manner: On two pounds of bones calcined to whiteneſs, I poured one pound of oil of vitriol, diluted with twelve pounds of water, and left it to ſtand in a warm place for ſeveral days, during which time I ſtirred it frequently with a wooden ſpatula. The whole was then put upon a canvas ſtrainer, and the earth edulcorated till it no longer taſted acid. Upon this the lixivium was evaporated to the quantity of two pounds, and decanted from off the gypſum that was depoſited by it. I then evaporated it to the conſiſtence of honey; and having added to it four ounces of powdered charcoal, put the whole together into a ſtone-ware retort, and expelled the phoſphorus by an open fire into a receiver containing water. After the rectification of this I obtained from it ten drachms and twenty grains. Vid. Eſprit des Journaux Avril, 1782, p. 311 †.

M. *Marggraf*

* Chemical Journal for the cultivators of Natural Hiſtory and Phyſic, General Œconomy, and Manufactures, by Dr. *Lawrence Crell*. Vol. I, Lemgo, 1778. [A]

† Mr. *Dolfuſs*, in his *Pharmaceutiſch-Chemiſche Erfahrungen* gives the following hint to thoſe manufacturers of ſal ammoniac, who make uſe of diſtilled urine in the proceſs. When the volatile ſpirit is all ſeparated from the urine by diſtillation, the reſiduum in the diſtilling veſſel may be farther evaporated to dryneſs; then mixed with powdered charcoal, and diſtilled for phoſphorus. In his experiments 100 lb. of urine yielded an ounce and a half of ſalt, and this ſalt mixed with powdered charcoal produced about fifty-four grains of clear tranſparent phoſphorus. According to the ſame chemiſt, the cheapeſt method of making phoſphorus with calcined bones, is as follows: The phoſphoric acid contained in twenty-four ounces of calcined bones is to be ſeparated by the addition of one pound of oil of vitriol, diluted with a ſufficient quantity of water, and the ſelenite reſulting from the combination waſhed ſeveral times with water with a view to deprive it of the adhering phoſphoric acid. The different liquors are then to be mixed together and evaporated; during the evaporation, a precipitation of a quantity of ſelenite, which was diſſolved in the diluted phoſphoric acid, takes place, and when the whole of the liquor amounts to about two pounds, the ſelenite is to be ſeparated by ſtraining the liquid through a very cloſe linen cloth. The clear phoſphoric acid muſt next be evaporated to the conſiſtence of an extract, and then put into a crucible to be evaporated ſtill farther. The acid will riſe very faſt like a foam; and the ſul-

phureous

M. *Marggraf* has moreover confirmed what had been already obſerved by *Albin* and *Hoffmann*, viz. that genuine phoſphorus may be prepared from certain vegetables. He obtained it from the ſeeds of the white and black muſtard, as alſo from garden-creſſes and wheat in the following manner: He put a pretty conſiderable quantity of each of theſe ſeeds into different retorts, and diſtilled them till the retorts exhibited an obſcure red-heat. He then took ſix ounces of each reſiduum, and having reduced it to powder by trituration, put each of them ſeparately into a well-coated retort of ſtone-ware; then diſtilling it with the moſt violent fire, obtained from every one of them a fine phoſphorus *.

In order to make ſome nearer approaches to the knowledge of the nature of phoſphorus, and diſcover what is actually the cauſe of its production, the following experiment of M. *Marggraf*, to whom we are indebted for the accurate knowledge we have of the conſtituent parts of this ſubſtance, muſt be taken into conſideration. In fact, he obtained an excellent phoſphorus by diſtillation from two parts of genuine eſſential ſalt of urine, and one of lamp-black that had been expoſed to a red-heat. But as this ſalt of urine conſiſts of a very peculiar

phureous vapours that eſcape from it, are almoſt intolerable. As ſoon as theſe ceaſe, the fire is to be raiſed till the crucible is red-hot throughout, and the acid fuſes like a metal. This acid when hot, is brittle and very much reſembles porcelain; but quickly attracts the moiſture of the air, for which reaſon it muſt be powdered immediately, and after being mixed with an ounce of powdered charcoal, put into a coated earthen retort. The diſtillation muſt be carried on very ſlowly in the beginning. Firſt there comes over a quantity of ſulphureous hepatic air with a few drops of water. Theſe are followed by the phoſphorus, which paſſes over as well in vapours as in drops. The diſtillation will be terminated in ſix hours, by which time the fire muſt be raiſed to ſuch a degree that the retort ſhall be quite buried in it. From this quantity of calcined bones, nearly five drachms of phoſphorus may be obtained, which is quite tranſparent, and requires no rectification.

Profeſſor *Crell* lately propoſed to the Chemiſts to make phoſphorus, by calcining two parts of calcined bones with three of cauſtic alkali, and ſeparating the phoſphoric acid from them by pouring into this mixture diſſolved in water a ſolution of quickſilver in nitrous acid, The quickſilver will be precipitated, combined with the phoſphoric acid; and this phoſphoro-mercurial precipitate, on being diſtilled with powdered charcoal, will yield phoſphorus. [D]

* This plainly indicates the manner in which the phoſphoric acid comes into animal bodies. [A]

acid, (which may be called the animal acid) and volatile alkali; we ſhould not even then have known principally what takes place with reſpect to the ſingular neutral ſalt we are ſpeaking of in this operation, had not this excellent chemiſt proceeded with his reſearch, and made the following experiment. Having mixed an ounce of the pure animal acid of this ſalt, which had been totally deprived of its volatile alkali, with an ounce of lamp-black that had been expoſed to a red-heat, he diſtilled them together, and obtained a drachm of very fine phoſphorus. In like manner the ſame chemiſt, by mixing two ſcruples of fine filings of zinc with two drachms of the acid of urine, and diſtilling this mixture in a glaſs retort, made an excellent phoſphorus, which aroſe from the phlogiſton of the zinc and the above-mentioned acid. The firſt-mentioned mode of preparing phoſphorus alſo confirms this theory in the ſtrongeſt manner.

Nothing therefore is more certain, than that, according to the ſyntheſis of this ſubſtance, *the conſtituent parts* of phoſphorus are, the peculiar animal acid, which may be extracted both from urine and the ſolid parts of animals, and phlogiſton. Conſequently phoſphorus is a ſulphur of a quite peculiar nature, which is decompoſed of itſelf, when expoſed to the open air, and is produced by the moſt violent action of fire from the two conſtituent parts abovementioned, by means of a combination of theſe parts. But the phenomena preſented by the analyſis of it, do not perfectly accord with this notion*. When phoſphorus is expoſed to the open air, it is gradually ſeparated into its conſtituent parts, a ſeparation that is attended with the continual eſcape of ſhining vapours: the abovementioned acid of urine and a ſmall portion of earth remaining behind. Now whence proceeds its ſhining property? whence originates the peculiar ſmell of garlic diffuſed by its luminous vapours? and from whence comes the earth that is left behind?

* On the contrary, the analyſis of this peculiar ſubſtance perfectly accords with the ſyntheſis. But the author is induced to doubt this from the peculiar idea he has formed to himſelf concerning the compoſition of phlogiſton. The firſt of the following Queries is eaſily anſwered by referring to the Introduction to this work. The ſecond remains unexplained as yet in every theory. The laſt poſſibly proceeds from the author's having miſtaken for an earth the portion of phoſphorus that had eſcaped total decompoſition, and which is what M. *de Morveau* formerly called the glacial phoſphoric acid. Vid. pag. 174. In fine, phoſphorus is a ſpecies of ſulphur, conſiſting, (not of the phoſphoric acid) but of the baſe of that acid and phlogiſton. [E]

The following properties alſo of phoſphorus are worthy of notice, as they ſerve at the ſame time to confirm the preceding notions. Phoſphorus, as has been mentioned before, is a ſulphur of a peculiar kind, and likewiſe, according to *Marggraf*, readily unites with common ſulphur. When therefore equal parts of phoſphorus and ſulphur are mixed together, and this mixture is diſtilled after undergoing a ſhort digeſtion, the phoſphorus combined with the ſulphur paſſes over into the water contained in the receiver. A farther remarkable circumſtance in this maſs is, that it is not eaſily kindled, even if it be rubbed with the fingers, but only ſhines with a yellow colour. But when it is expoſed to a dry heat equal to that of warm water, it is inflamed with a fierce flame, and the vapour iſſuing from it has quite a ſulphureous odour; indeed, the whole maſs ſmells quite like liver of ſulphur, and ſwells up in water, and communicates to this element not only a ſtrong ſulphureous ſmell, but alſo a perceptibly acid taſte. It is likewiſe remarkable, that when this ſame phoſphorated ſulphur is mixed with ſilver and diſtilled, the phoſphorus comes over in the form of a *tranſparent thin oil*, which in the water ſinks to the bottom of the veſſel, at the ſame time preſerving its fluidity. The ſilver remains behind, and has the appearance of the vitreous ſilver ore, but it is withal very brittle. An ounce of ſmoking ſpirit of nitre being poured upon a drachm of phoſphorus, in a ſmall retort, produced ſuch a heat during the time that the nitrous acid began to diſſolve the phoſphorus, that the major part of the nitrous acid, without the intervention of fire, paſſed over in red vapours into the receiver; at laſt the phoſphorus was inflamed with the greateſt violence, and burſt the retort with an amazing loud report. When ten grains of phoſphorus are triturated in a glaſs mortar together with an ounce of very dry purified nitre, the phoſphorus breaks out into flames, and detonates with the nitre. Phoſphorus may alſo be diſſolved in genuine unadulterated oil of cloves, and by this means brought into a liquid form. This oil becomes luminous as ſoon as it comes into contact with the air, and communicates the ſame property to all bodies that are rubbed over with it. When phoſphorus is inflamed by a gentle heat under a glaſs bell, light delicate flowers are ſublimed, which deliqueſce in the air to an acid liquor; but the phoſphorus burned in this experiment is increaſed in weight at the rate of three drachms and a half in the ounce *.

Inſtances

* In addition to the Hiſtory of the Phoſphoric acid it may be proper to obſerve, that M. *Kunſemuller* has diſcovered both the oxaline and phoſphoric acid in Galls. Vid. Chemical Annals, 1787.

Inſtances of *imperfect* phoſphori are: 1. *Homberg's Phoſphorus*, into which, while in a ſtate of fuſion, an iron rod being dipped, and thus incruſted with it, gives out a light, whenever it is ſtruck with any hard body. For the preparation of this phoſphorus, ſee page 253. Another inſtance mentioned by *Meyer* is as follows. This Chemiſt having impregnated lime with olive oil, and extracted what he could of this compoſition by means of ſpirit of wine, and then preſſed out the reſiduum, finally diſſipated the ſpirit, that was ſtill contained in this latter, by combuſtion. The ſubſtance that remained behind yielded a tolerable bright phoſphoric light in the dark, which was diffuſed more ſtrongly, when the maſs was cruſhed in pieces, and which laſted as long as the maſs was warm, and even was renewed, when this latter was ſtrongly heated again. To theſe may be added lump-ſugar, which, like the foregoing, may be made to ſhine in the dark, by friction.—A ſtill better claim to the title of phoſphori is exhibited by the fluor ſpar, ſeveral ſpecies of the Cadmia fornacum, and of the Scharfenberg Blend, all which emit a phoſphoric light merely on the application of heat. The light emitted by the diamond, in conſequence of friction, appear to be preferable to electricity; the cauſe of that emitted by flint under the ſame circumſtances does not appear as yet to be ſufficiently underſtood. Moſt, if not all of the ſubſtances here referred to, are in ſome meaſure decompoſed by the friction or calefaction they have undergone; at leaſt they loſe their property of ſhining in the dark: a circumſtance in which they agree with the phoſphorus of urine: from

1787, Vol. II, page 413, where he likewiſe offers ſome reaſons tending to prove that the vegetable and phoſphoric acids are one and the ſame acid. He likewiſe ſuppoſes that the phoſphoric acid, united with extractive matter and phlogiſton, conſtitutes the vegetable acid; and aſſerts that it is the phoſphoric acid in galls, and not the oxaline, that ſtrikes a black colour with iron.

To this account of the compounds formed by the phoſphoric acid, may be added, that M. *Prouſt* has found whole hills of calcareous photocrate, vid. p. 257, in the diſtrict of Truxillo in the province of Eſtremadura. It abounds ſo much in the environs of the village of Logroſan in that diſtrict, that the houſes and encloſures there are conſtructed of it. This ſtony matter, when ſprinkled upon live coals, inſtead of decrepitating, burns tranquilly, with a beautiful green flame or light, that ſeems to penetrate its whole ſubſtance. *Journal de Phyſique*. Mai, 1788.

It ſhould likewiſe be obſerved, that according to M. *Berthollet*, white phoſphorus is phoſphorus combined with a quantity of air not ſufficient to acidify it. In this circumſtance it greatly reſembles the white calx of arſenic. M. *de Morveau* has very improperly denominated this, *baſe acidifiable de phoſphore*; for the baſe of the phoſphoric muſt be that which is combined with no air at all: and is the ſame as the baſe of phoſphorus itſelf, which it accordingly forms by ſimple union

from which they ſeem to differ only in the degree of heat neceſſary to be applied, in order to ſeparate the light contained in their ſubſtance.

union with phlogiſton; and with air, phoſphoric acid, or white phoſphorus, according to the different proportions of theſe two ſubſtances.

Common phoſphoric glaſs, M. *Berthollet thinks*, probably retains a greater or leſs quantity of vital air than white phoſphorus. [E]

CHAP.

# CHAP III.

## PYROPHORI.

NEXT to theſe, the *Pyrophorus* deſerves to be noticed as a body, which is accended without the intervention of any other ignited ſubſtance. Under this appellation is underſtood an artificial carbonaceous product, which on being expoſed to the open air, glimmers like a live coal. Hence in the German language it has obtained the name of *Luft-zunder*, or *Air-tinder*. It is prepared from alum by calcination, with the addition of various phlogiſtic ſubſtances. *Homberg* was the firſt that obtained it, which he did accidentally in the year 1680, from a mixture of human excrement and alum, upon which he was operating by fire. This Chemiſt, upon the ſtrength of ſome information communicated to him, was endeavouring to extract by diſtillation from human excrement, an oil that ſhould tranſmute mercury into ſilver; in this attempt however he was diſappointed, as might naturally be expected. *Lemeri* the younger, afterwards, in the year 1713, ſhewed that it could not only be prepared from this ſubſtance, (but alſo on being previouſly mixed with alum) from various other bodies, that are capable of being charred. After this, M. *de Suvigny* made it appear, that by the addition of any inflammable body whatever, a phoſphorus may be made of all ſuch ſubſtances as contain vitriolic acid combined either with earth or with alkaline ſalt, or with a metallic ſubſtance. Notwithſtanding this the preference is given to alum, becauſe its earth beſt retains the vitriolic acid in the fire, and hence the operation ſucceeds beſt with this ſalt.

The *preparation* is managed in the following manner. Three parts of alum are mixed with from two to three parts of honey, or ſugar, and this mixture is dried over the fire in a glazed bowl, or an iron pan, diligently ſtirring it all the while

while with an iron ſpatula. At firſt this mixture melts, but by degrees it becomes thicker, ſwells up, and at laſt runs into ſmall dry lumps. Theſe are triturated to powder, and once more roaſted over the fire, till there is not the leaſt moiſture remaining in them, and the operator is well aſſured, that it can liquefy no more; the maſs now looks like a blackiſh powder of charcoal. For the ſake of avoiding the previous above-mentioned operation, from four to five parts of burned alum may be mixed directly with two of charcoal powdered. This powder is poured into a phial or matras, with a neck about ſix inches long. The phial, which however muſt be filled three quarters full only, is then put into a crucible, the bottom of which is covered with ſand, and ſo much ſand is put round the former that the upper part of its body alſo is covered with it to the height of an inch; upon this the crucible, with the phial, is put into the furnace, and ſurrounded with red-hot coals. The fire being now gradually increaſed till the phial becomes red-hot, is kept at this pitch for the ſpace of about a quarter of an hour, or till a black ſmoke ceaſes to iſſue from the mouth of the phial, and inſtead of this, a ſulphureous vapour exhales, which commonly takes fire. The fire is kept up at this pitch till the ſulphureous flame is no longer to be ſeen. Upon this the calcination muſt be put an end to, and the phial cloſed for a ſhort time with a ſtopper of clay or loam. But as ſoon as the veſſel is become ſo cool as to be capable of being held in the hand, the phial is taken out of the ſand, and the powder contained in it transferred as faſt as poſſible from the phial into a dry and ſtout glaſs made warm, which muſt be ſecured with a glaſs ſtopper.

For the production of this pyrophorus, it is neceſſary that there ſhould be in its compoſition a newly generated ſulphur, an inflammable coal, concentrated matter of fire, and calcined earth of alum, or ſome other fixed body, with which the newly generated ſulphur may unite. M. *Scheele* concludes from his experiments, that fixed alkali is requiſite for the production of pyrophorus, and mentions the following as proofs of it; that from a mixture of liver of ſulphur with calcined alum and a little powdered charcoal, he obtained after calcination a good pyrophorus. The ſame effect took place when he had mixed together and calcined a ſpoonful of finely triturated vitriolated tartar, with three ſpoonfuls of charcoal reduced to a fine powder; both theſe experiments I have found to be juſt as the author has related them; but nevertheleſs do not conceive the neceſſity of fixed alkali, becauſe there are alſo pyrophori, which do not contain any

any fixed alkali at all. Probably the alkali ſerves only to retain and fix the ſulphur in the ſame maner as the earth of alum does, and perhaps does this better, and therefore may be uſed in its place, to which purpoſe alſo ſeveral other ſubſtances ſeem to be adopted.

The opinions of Philoſophers relative to this phenomenon are in like manner very different. Some Chemiſts have pretended with *Suvigny*, that there is to be found in the pyrophorus a highly concentrated vitriolic acid, which greedily attracts the moiſture of the air, and is by this means ſo intenſely heated, that the ſulphur, together with the coaly ſubſtance, is inflamed by it. This opinion, however, can by no means be admitted; ſince there is no acid in the pyrophorus perceptible to the ſenſes; on the contrary, this ſubſtance has manifeſtly the taſte of liver of ſulphur, and diſſolves, like liver of ſulphur, without affording any other ſmell than that which accompanies every ſolution of hepar ſulphuris. But if an uncombined acid were contained in it, that peculiar volatile and ſuffocating ſulphureous vapour muſt inevitably be perceived, which is always produced upon the admixture of an acid with a ſolution of liver of ſulphur. And indeed, in what part of it ſhould this uncombined acid be contained? The quantity of acid that quits the earth of alum will either be converted into ſulphur by the phlogiſton, or muſt fly off from the maſs in conſequence of the heat employed in the preparation. If it be ſaid, that it remains united with the earth of alum, in this caſe it would not be a diſengaged acid, and then its property of rapidly attracting water, and its conſequent incaleſcence, which have been adduced as the cauſe of this phenomenon, are annihilated. This caſe is alſo impoſſible upon the whole; as an aluminous compound and liver of ſulphur cannot be placed in contact with each other without the former decompoſing the latter; and in fact, the ſolution of pyrophorus is precipitated by a ſolution of alum, with a diſagreeable odour. Therefore there muſt neceſſarily be another reaſon for the inflammation of this compound.

When we conſider the ſubſtances employed in thepreparation of pyrophorus, and the changes they undergo during the operation, no other judgment can be formed, than that from the vitriolic acid of the alum (which among other ingredients is uſed in making the pyrophorus) with part of the inflammable ſubſtance that was added to it, by means of the fire a ſulphur muſt ariſe, which however remains united with the earth of alum deprived of all its acid, and with the remaining carbonaceous part, the earth of alum being now put into a *ſtate ſimilar to that of*

*quick-lime*, no inflammation can be conceived without the matter of fire acting as the occasional and efficient cause, this must necessarily be taken up in a considerable quantity into all the interstices of the earth of alum, now deprived of all its adherent acid. Now, as in every part of this mixture every particle of the aluminous earth, perfectly calcined, and deprived of its fixed air, is accompanied by a minute particle of charcoal, as well as of the newly generated sulphur; it seems to me, that the matter of fire which lay at rest in this mixture, and without any excitation ab extra, being now put into action by the air coming into contact with it, first kindles the particles of charcoal conformably to their nature, which then rapidly propagate the conflagration to the molecules of sulphur that lie next them. In this view of the subject the reason is manifested, why, in the composition of a pyrophorus, a fixed body is requisite, with which part of the sulphur may be intimately combined *.

Besides

* More theories of the cause of the inflammation of the pyrophorus are to be found in the German edition of *Macquer's* Dictionary of Chemistry, Vol. IV. page 128—131; among which that laid down by Professor *Leonhardi* deserves the preference. [A]

As many doubts have been raised concerning this theory, I shall here mention the most striking and plausible objections. M. *Scheele* [*Scheele*'s Chemical Observations and Experiments on Air and Fire, translated by Dr. *Forster*, sect. 81, p. 128,] exposed pyrophorus to moist phlogisticated air, without observing any ignition to ensue. A still further proof of the insufficiency of this theory is offered by an experiment made by Mr. *Bewley*, in *Priestley*'s Experiments and Observations on Air, Vol. III. This philosopher found, that notwithstanding that, by a repeated calcination of vitriolated tartar and charcoal, much of the vitriolic acid was lost, yet a pyrophorus might be obtained, with a fresh addition of powdered charcoal, and even with the addition of an alkaline substance that exceeded the whole of the acid in quantity. Mr. *Bewley* obtained a pyrophorus likewise from calcined vitriol; from aluminous earth as free as possible from vitriolic acid, and from crocus martis, by the calcination of these substances with powdered charcoal and vegetable alkali. He even made a good pyrophorus, without any vitriolic acid, to which he gave the name of alkaline pyrophorus, in conseqence of his having obtained it by the calcination of the coal of blood with vegetable alkali; the colouring substance of which had been already extracted for the precipitation of the Prussian blue: whether the alkali employed was common alkali, or purified salt of tartar or fixed nitre, the result was always the same; and it will appear farther on, when I shall have occasion to mention some other kinds of pyrophorus, which do not contain any alum, that there are other substances besides, that yield pyrophori, without containing the least particle of vitriolic acid.

The necessity for the presence of moisture, as well as of pure air, for the accension of pyrophori, appears evident from *Scheele*'s Experiments. This great observer having made the air in a matras thoroughly dry with quick-lime, and two days after put some pyrophorus in it, could not

 perceive

Beſides this, other compoſitions, which, in like manner, take fire on expoſure to the open air, have been by degrees made known to us: 1. the ſcoriæ of the

perceive that it even grew warm, On the other hand, when he put a wet ſponge into the matras, and carefully cloſed the latter, the pyrophorus kindled in the ſpace of a few minutes. The pyrophorus however would not by any means take fire in phlogiſticated air. On the other hand, Mr. *Bewley*'s Experiment, according to which, the pyrophorus kindled on dry paper, or dry tint and ſo near the fire that ſome dry cauſtic alkali placed in the ſame ſituation did not get any moiſture from the air, (and likewiſe on a hot iron plate) ſeem to ſhew, that the pyrophorus will kindle without attracting any moiſture from the air; but here it may be ſufficient to obſerve in general, that the motion of the heat, which is excited in the aluminous pyrophorus, is the cauſe of the acceenſion of this ſubſtance; and this motion of the heat may either ariſe, as in the Experiments above-mentioned, from heat applied ab extra, or, (as is the caſe when expoſed to the common temperature of the atmoſphere) by attracting the moiſture of this latter. Mr. *Bewley* thinks that pyrophori have the power of decompoſing the atmoſpheric air, and of attracting the nitrous air from it, and by this means of exciting ſuch a heat that the phlogiſtic particles of the pyrophorus are capable of being kindled by it. He founds his opinion upon various experiments of Dr. *Prieſtley*, who with nitrous acid, obtained from ſeveral ſubſtances very pure dephlogiſticated air; as likewiſe on having been able to ſet fire, by means of nitrous acid a pyrophorus that had not been ſufficienly calcined. All pyrophori are, as he thinks, nothing but perfectly dry alkalies combined with phlogiſtic matter, which, in conſequence of the attraction of the air emit this phlogiſtic matter, when this laſt immediately ſeizes the nitrous acid exiſting in the air, and forms a nitrous ſulphur, that is very eaſily decompoſed, and is kindled in conſequence of the heat produced by the combination.

M. *Scheele* gives the following explication of the accenſion of pyrophori. The liver of ſulphur, of which, together with charcoal, this preparation coſiſts, attracts the phlogiſton that has been extracted from the charcoal during the calcination. This ſubſtance, which is compoſed of alkali, phlogiſton and ſulphur, will not take fire without moiſture and dephlogiſticated air. The alkali, which attracts the moiſture ſtrongly, is rendered incapable by it of retaining the phlogiſton any longer, eſpecially as empyreal or dephlogiſticated air is preſent, a ſubſtance which attracts the phlogiſton more powerfully. Now, in conſequence of the empyreal air combining with the looſely adhering phlogiſton, a quantity of heat is generated, which, together with the freſh acceſſion of empyreal air, kindles the ſulphur and charcoal, and afterwards calcines them.

M. *Pilatre de Rozier* aſſerts, that a certain quantity of phoſphorus exiſts in the pyrophorus, and is the cauſe of its inflammation: for he ſuppoſed the acid of all mucilaginous ſubſtances to be the phoſphoric acid. This philoſopher obtained from fifty-four grains of flowers of ſulphur, thirty-ſix grains of charcoal made of willow, and three grains of phoſphorus, a kind of pyrophorus which took fire in conſequence of being breathed upon, and which, on the addition of twenty-four grains of alkali, emitted a ſulphureous ſmell, ſimilar to that of the aluminous pyrophorus.

Inſtead

the martial regulus of antimony, as well crude as alſo after being diſſolved, have been obſerved to take fire ſpontaneouſly, when laid upon a hot ſtone, or in the ſun. Of the

Inſtead of entering into tedious diſquiſitions for the purpoſe of examining and confuting theſe ſeveral opinions, I ſhall beg leave to adduce that of M. *Leonhardi*, which appears to me to be the moſt ſatisfactory of any hitherto offered to the public. "As, ſays this Author, beſides the aluminous, there are other kinds of pyrophori, in which neither phoſphorus, nor ſulphur, nor liver of ſulphur can be ſuppoſed to exiſt, we muſt ſeek for ſuch an explanation as ſhall be equally adapted to them all. And this appears to me to be found in the inflammable air which is kindled by the heat in conſequence of the acceſſion of the reſpirable air to it." This theory he attempts to eſtabliſh by the following arguments: "A quantity of inflammable air is actually produced in the preparation of the aluminous pyrophorus from burned alum, and a charred vegetable or animal ſubſtance."

I. "For if this mixture be calcined in *Bewley's* method, viz. covered up with ſand in a tobacco-pipe, a ſort of effervefcent motion may be obſerved in the ſand, which ſeems to ariſe from ſome kind of air that is extricated from it."

II. If the pyrophorus be prepared, as it uſually is, in an open phial, into which conſequently the external air can enter, a flame is produced, which is nothing but an inflammable air, generated by the vitriolic acid that is detached from the alum, and on occaſion of the maſs being heated, acts upon the coal, and, (on the acceſſion of the external air) kindled by the heat ſubſiſting near the mouth of the phial. This flame is likewiſe the mark of the operation being nearly finiſhed. If the pyrophorus be calcined till it yields no flame at all, it will never be good, becauſe all the inflammable air is expelled. If the calcination be diſcontinued before the flame becomes weak, it will be but an imperfect pyrophorus; becauſe the alkali contained in it is not dry enough to attract the moiſture in the air, ſo as to generate a ſufficient degree of heat. If, on the other hand, the proceſs be diſcontinued, at the time that the flame begins to get weaker, a part of the inflammable air remains in the phial upon the coaly powder, and is abſorbed by it, if the evaporation of it be prevented as uſual. For it is proved by the Abbé *Fontana's* experiments that coals abſorb all kinds of air, and conſequently inflammable air. But this inflammable air being but very looſely combined, a very low degree of heat will be able to kindle not only the inflammable air itſelf, but likewiſe by means of it, the coal and ſulphur of the pyrophorus; whether the heat, as in *Bewley's* experiments, be occaſioned ab extra, by actual fire placed at ſome diſtance, or, as *Bewley* likewiſe experienced, by pouring upon the pyrophorus a drop of the concentrated nitrous acid, (which, according to *Scheele's* experiments, cannot decompoſe the inflammable air) or, laſtly, (as takes place on the expoſure of it to the air,) in conſequence of the moiſture of this latter being attracted by the alkali.

The inflammable air contained in the aluminous Pyrophorus ſeems to be of the nature of hepatic air, as an odour ſimilar to that of this air is obſerved to ariſe during the burning of the pyrophorus. The pyrophorus when kept in a looſe, careleſs manner, loſes the property of kindling in the air; becauſe the moiſture which it has ſlowly and gradually attracted from the air, prevents its incaleſcence in the air, and perhaps becauſe the inflammable air in part evaporates.

 But

the truth of the latter caſe I am aſſured by my own experience: Secondly, Some aſſert that they have obſerved an inflammation enſue from honey and flour calcined

But a repeated calcination will reſtore to it this property: becauſe it renders the alkali extremely dry, and makes it able to generate heat again, by attracting the moiſture of the air; and probably alſo there is a freſh extrication of inflammable air.

The ſame explication will hold good with reſpect to every kind of pyrophorus made of charcoal, alkali, and calcined vitriols, or vitriolic neutral ſalts, and even to Mr. *Bewley's* pyrophorus, which conſiſts of alkali and charcoal. This is confirmed by an experiment of *Scheele*, in which, by diſtilling cauſtic alkali and charcoal together, a quantity of inflammable air was obtained free from fixed air. [D]

Finally, the Gentleman, to whom the Editor is obliged for this long Note, is of opinion with M. *Macquer*, that the matter of light and phlogiſton are the ſame, and that the pyrophorus containing ſome part of this phlogiſton in a looſe ſtate, as being redundant, the phlogiſton is ſet on fire by the motion of the heat which the pyrophorus undergoes, either by expoſure to the air or by any other means, and by this inflammation the pyrophorus is in part decompoſed.

The Editor himſelf ſtated his opinion in a curſory manner on this matter ſome years ago, in his *Eſſay on Fire*, viz. that the phlogiſton exiſted in theſe bodies in a looſe ſtate of union; vid. page 53, 54 and 63. Though the great variety of objects comprized by his ſubject did not permit him at that time to be more particular in his explication of this phenomena, yet M. *Scheele's* truly ingenious experiments and inferrences did not by any means eſcape his notice; but at the ſame time it was very evident to him that a more general and extenſive cauſe was to be ſought for; and this he ſought and found in the general looſe manner in which the phlogiſton of theſe bodies was united to their reſpective baſes. Whatever effects this is the genuine efficient and proximate cauſe of the phenomenon. Now heat has the ſame effect as water in this caſe, though a much more general one, and extending to a much greater number of bodies. Water then does not promote the accenſion of the pyrophori by producing heat, a ſuppoſition (conſidering the very minute quantity of it that is admitted) manifeſtly abſurd: but rather acts on theſe bodies in the ſame manner as heat, viz. by weakening the mutual attraction of the ſeveral conſtituent parts. Now the attraction of the phlogiſton to the baſe of the pyrophorus being by this means ſufficiently weakened, the pure air of the atmoſphere has an opportunity of uniting (not with the phlogiſton, as *Scheele*, and indeed the Editor himſelf for want of a thorough knowledge of the theory of combuſtion ſince publiſhed by M. *Lavoiſier*, then imagined, but) with the baſe to which the inflammable principle is itſelf looſely united, which in moſt caſes is the carbonaceous, or vegetable principle: though the bond of union between them being diſſolved, the phlogiſton eſcapes in the form of heat and light, and, as in common combuſtions, the body is deſtroyed, or rather enters into new combinations.

Since writing the above, the Editor has obſerved in the 6th Volume of *Prieſtley*, a pretty ſtrong coincidence in opinion between Mr. *Keir* and himſelf on this ſubject with reſpect to the matter

cined according to the rules laid down above: Thirdly, According to *Geoffroy*, a calcined mafs of three parts of black foap and one of diaphoretic antimony has been known to take fire fpontaneoufly: Fourthly, *Meuder* has obferved, that a pyrophorus arifes when equal parts of orpiment and iron filings are fublimed together, and ten parts of this fublimate are triturated in a mortar along with twelve of nitre of filver: Fifthly, a pyrophorus is produced, according to *Penzky*, when two drachms of white fand, three of common falt, one of fulphur, two of oil of vitriol, and half an ounce of fpirit of falt are mixed together, and diftilled in a glafs retort. In this operation a fublimate is faid to be obtained, which burfts out in flames, as foon as it comes into contact with the air: Sixthly, The fpontaneous precipitate of Ofteocolla from a folution of it in vitriolic acid, after having been feparated by means of a filter, and dried, took fire in a warm place: Seventhly, *Pott* obferved the fame phenomenon in the earth of the refiduum after the diftillation of urine, that had been putrid for a confiderable time. To thefe may alfo be referred, Eighthly, A mafs compofed of equal parts of fulphur and of iron filings, which when thoroughly moiftened with water, after fome time grows hot, fwells, and at laft breaks out into vapour, fmoke and flame. It is difficult to difcover the caufe of thefe and feveral other fimilar experiments, as

matter that occafions the inflammation, but Mr. *Keir*, who afferts that inflammable animal, or vegetable matter is an effential ingredient in every pyrophorus, feems in this inftance to have drawn too general a conclufion, which is contradicted by a variety of phenomena, fome of which are mentioned by our author in the next paragraph. [E]

Thofe pyrophori that require a heat greater than that of the ufual temperature of the atmofphere for their accenfion, may be termed *imperfect* pyrophori. They may be compared to the imperfect phofphori, and are, in fact, intermediate fubftances between the true pyrophori and ordinary combuftible bodies. Moft of the following, taken from M. *Bucholz*'s paper, in Vol. I. of the Chemical Annals, are of a different nature, and appear to be the refult of fermentation, or the decompofition of water.

With a view to the prevention of fires, in many inftances it may be ufeful to make mention in this place of certain fubftances which, when made warm to a certain degree, or merely mixed with oils, take fire and are deftroyed. On occafion of a Frigate that in 1781 took fire in the Port of Cronftadt, juft as fhe was preparing to fet fail, though no fire had been made in her for five days before, M. *Georgi* of the Imperial Academy of Peterfburgh made a great number of experiments, from which we fhall felect the moft remarkable. He impregnated gradually three pounds of Pruffian lamp-black with five pounds of boiled hemp-feed oil, and after having left the mixture expofed to the air for about five hours, wrapped it up in a coarfe linen cloth,

This

as the circumſtances attending them are complicated, whence the cauſe cannot be well aſcertained. We learn however by this, that other fixed bodies beſides may have

This maſs, after having lain in a cheſt for about ſixteen hours, yielded a very offenſive and ſeemingly putrid ſmell, not much unlike that of boiling oil. Some parts of the maſs grew warm, then hot, and emitted a conſiderable quantity of vapour. Theſe vapours were watery, and by no means inflammable. Within about eighteen hours after the packet was made, ſome part of it growing warm, exhibited ſmoke, and immediately afterwards was actually ignited. The ſame happened at two or three other places; but others were ſcarcely warm. The fire ſpread very ſlowly, and emitted a thick ſtinking ſmoke. M. *Georgi* then taking the maſs out of the cheſt and laying it on a ſtone floor, where it was more expoſed to the air, a flame about ſix inches high aroſe with much ſmoke: whenever any openings or crevices were made in the maſs, they threw out vapours which ſoon after took fire. The maſs being thrown upon the floor, broke in pieces, and a briſk flame aroſe on a ſudden about three feet in height, which ſoon ceaſed, when the materials continued to glimmer, at firſt with ſmoke, and afterwards without, for the ſpace of ſix hours. The whole was conſumed in about eight hours. The aſhes which were grey, weighed, when cold, five ounces and a half.

In another experiment exactly ſimilar to this, as to what relates to the mixture and quantity of the materials, the inflammation did not take place for forty-one hours after the oil had been imbibed by the lamp-black. In general the inflammation took place much ſooner in fine clear days than in rainy weather.

In another experiment he impregnated three pounds of Ruſſian lamp-black with three pounds of hemp-ſeed oil unboiled, and the inflammation took place in the ſpace of nine hours.—Twelve ounces of fine German lamp-black mixed with twenty-four ounces of boiled hemp-ſeed oil, did not grow warm till after ſeventy hours were elapſed; it then became gradually hotter, and emitted vapours which were not inflammable. The re-action of the materials laſted about thirty-ſix hours, in which time the heat was ſometimes greater and ſometimes leſs, till at laſt it ceaſed entirely. He made a great many more experiments for the Board of Admiralty at Peterſburgh, of which I ſhall relate the reſult only. The inflammation takes place much ſooner when Ruſſian lamp-black, which is coarſe, greaſy, and heavy, is impregnated with the oil, than when the German lamp-black, which is light and fine, or common wood-ſoot is employed for this purpoſe. With regard to the oils, the inflammation only happens with drying oils, either boiled or crude. The proportion of the lamp-black to the oil differed greatly in theſe experiments; the lamp-black or ſoot took fire with $\frac{1}{10}$, $\frac{1}{5}$, $\frac{1}{3}$, $\frac{1}{2}$, equal parts, and even with twice the quantity of the oil. In general the inflammation depended more upon the mode of mixing the ingredients than upon the quantity of them, and alſo, as M. *Georgi* often obſerved, upon the weather; for in wet weather the maſs after growing warm, became warm again. A pacquet of hemp, of about thirty pounds weight, was impregnated with a mixture of three pounds of tallow and three pounds of hempſeed-oil, and put into a baker's oven, which was heated to 90 degrees of *Fahrenheit*; on taking it out of the

have the ſame effect as, in the uſual mode of preparing pyrophorus, appears to be produced by the earth of alum*.

Upon

the oven an hour afterwards it was hardly warm. In the ſpace of an hour after this it began to ſmoke, and in another hour the ſpontaneous inflammation took place; when M. *Georgi* obſerved that it began about the ſurface and not in the middle of the maſs. He attributed much to the dry wind that blew on that day. The pacquet burnt for the ſpace of five hours with a viſible flame.

Subſequent to theſe experiments with hemp and flax this ingenious philoſopher made others with wool: he impregnated twenty pounds of wool with a mixture of two pounds of hemp-ſeed oil and one of tallow; after having mixed the wool equably with oil, he put it into a ſmall baker's oven, and kept it there for the ſpace of an hour, after which he took it out and ſewed it up in a mat. The pacquet cooled by degrees, and remained in that ſtate three days, at the expiration of which period the wool was found quite ſound and entire, and the fat was ſo thoroughly imbibed by the wool that it was ſcarcely perceptible. On the ſame wool he now poured a pound of hemp-ſeed oil, and put it again into a baker's oven, of which the heat was 95° of *de Liſle's* thermometer. After remaining there an hour, it was tied up in a coarſe linen cloth, and laid on ſome wood in the laboratory. A few hours after the pacquet grew warm in ſome places, and emitted a ſlight ſmoke, which increaſed to that degree that two hours afterwards a ſpontaneous inflammation took place. The fire glimmered ſlowly, but when the window was opened, it burned for half an hour with a low flame; in the ſpace of forty-four hours it ceaſed burning, when there remained two pounds and ſix ounces of coal, and two pounds of very fine aſhes.

He made a great many experiments beſides, in which the ſpontaneous inflammation took place, ſuch as ſteeping cow-hair and wool in oil, and then expoſing them to a certain degree of heat, &c. from which may be drawn this general conluſion, viz. that oils, mixed either with vegetable or with animal ſubſtances, after they have parted with all their water, begin to take fire. The heat may either have been occaſioned by an inteſtine motion, as is the caſe when oils are mixed with coarſe lamp-black, or with black wad, where, by the internal heat, the whole of the fluid previouſly evaporates, the inflammation not taking place, till the water is evaporated; or elſe, when vegetable or animal ſubſtances are impregnated with oils, when the oil in conſequence of the great ſurface given it, parts with its water ſo much the ſooner, and thus acquires a ſolid and ſubſtantial body, with which it can take fire. This inflammation takes place, as Meſſrs. *Hagemann* and *Geller* have obſerved in *Crell's* Chemical Annals, 1784, page 488, in the apothecaries ſhops, in oils that are boiled till they are deprived of all their water.

M. *Georgi* alſo roaſted barley-groats and rice, and he found that the larger the grains are, the leſs they are diſpoſed to take fire: thus coffee roaſted brown, and bound up in linen did not kindle, the contrary to which however was the caſe with ground coffee, which took fire in three quarters

The confideration of the different kinds of Pyrophori naturally lead us to that of ordinary combuftible bodies, which differ from the pyrophori only in the degree of heat at which they are kindled. But as thefe have been fufficiently

quarters of an hour, and continued fpreading till half an ounce of afhes remained out of two pounds of coffee. In order to fatisfy himfelf that it was only the fize of the coffee-berries that prevented the mutual action of the component parts, the above-mentioned coffee was ground and roafted again tolerably brown, and wrapped up in linen. In an hour after this the powder took fire. Saw-duft of mahogany wood was roafted over a gentle fire till it was of a brownifh hue, and kindled in a quarter of an hour after it had been wrapped up.

Two pounds of fawduft of fir-wood, on account of the different fize of the particles, became partly black in roafting, and partly white. After being wrapped up it foon loft its heat; but an hour after the heat returned with fmoke, when quickly it took fire.

In order to know whether the compreffion of vegetable fubftances, and the modification of the air by furrounding them with linen, were effential to the fpontaneous inflammation, and whether a fpontaneous inflammation would take place without the obfervance of this circumftance, M. *Georgi* roafted fome barley-coffee till it was brown, which he put into a fhallow pot, without covering the latter entirely with its lid. After fourteen hours were elapfed, the warmth of the pot returned, and a fmoke arofe. There was no fire perceived in the dark; the infide of the pot however had a phofphoric appearance, and paper and bits of wood foon took fire, and a knife, upon being plunged into the mafs, became red-hot. In twenty-four hours the fire was extinguifhed.

The following remark of M. *Georgi* is of the greateft importance: in the drying of malt, and in roafting of other fubftances of a fimilar nature, the malt or other materials may take fire of themfelves in a corner of the kiln, a long time after the operation is finifhed, and that even in the open air, and without giving any figns of accenfion, except a trifling degree of fmoke, burn for a confiderable time, and do a great deal of mifchief. From all that has been mentioned, it appears, that the fmaller kinds of grain, as well as flour, fawduft, and other minutely divided and inflammable fubftances, when taken in confiderable quantities, and united with oily matters, are capable of taking fire of themfelves under certain circumftances, in confequence of their being furcharged with inflammable particles, as well as of an inteftine motion and mutual action in their conftituent parts, by which the inflammable particles are difengaged. This is certainly a very remarkable, and hitherto not fufficiently inveftigated property of many fubftances appertaining to the vegetable and animal kingdoms, the knowledge of which is very important for the farmer, the manufacturer, and artift. [E]

* Some other kinds are mentioned in M. *Bucholz's* Contributions to the Hiftory of Subftances that take fire of themfelves, in the Chemical Annals, Vol. I, page 411—418, and 484—500. (See the preceding note) On the fubject of a liquid Phofphorus, Vid. *de Morveau*, *Maret* and *Durande's* Elements of Theoretical and Practical Chemiftry, Vol. III, pag. 30. For Pyrophoric Tapers, Vid. Neuefte Entdeck. in der Chemie. Vol. IX, page 88. [A]

investi-

inveſtigated in the former part of this Work, we ſhall paſs on to another remarkable phenomenon nearly allied to the preceding, viz. the Inflammation of Oils by means of acids.

The *Inflammation of Oils* by means of the ſmoking acids, takes place alſo under different circumſtances, according to the different nature of the oils. The ethereal oil of ſaſſafras-wood, of cloves, and the reſt of the Indian ſpices, are inflamed, by adding to them an equal quantity of ſmoking nitrous acid. Under the ſame circumſtances likewiſe the inflammation takes place of the eaſily drying unguinous oils, as for inſtance, of linſeed-oil, oil of poppy-ſeeds, &c. in like manner, as moreover the empyreumatic oil of guiaiacum-wood has been obſerved to be inflamed by the ſmoking nitrous acid alone. But when the ethereal oil of turpentine, or the other fat oils, which dry ſlower, ſuch as oil of rape-ſeed, of olives, almonds, &c. are to be inflamed in this manner, about two drachms of the ſmoking ſpirit of nitre, and the ſame quantity of oil of vitriol muſt be previouſly mixed together in a glaſs, to which four drachms of oil of turpentine, or of one of the laſt mentioned unguinous oils, are then to be added with proper caution. In all theſe mixtures the acid is uſually poured into the oil by little and little; however the oil may alſo be poured into the acid, and that at once, but then it ought to be done in a place where there is no reaſon to apprehend any bad conſequences from it *. In order to explain this effect, it ought to be conſidered, that the nitrous acid acts ſtrongly upon every phlogiſticated ſubſtance, and that this active power increaſes in proportion to the concentrated ſtate of the acid; farther, that there exiſts in concentrated nitrous acid, a conſiderable quantity of free and pure matter of fire almoſt in a kindling ſtate. Now, as in the commixture, the nitrous acid acts powerfully upon the phlogiſton of theſe oils, a ſulphureous compound is generated, which is a *real nitrous ſulphur*, and is highly inflammable †. This is alſo inflamed here, becauſe

* I beg leave to obſerve, by way of caution to the unwary, that having ſome time ago poured a quantity of oil of turpentine into a mixture of ſmoking nitrous acid and oil of vitriol, a flame at that very inſtant burſt forth, accompanied with a very loud exploſion, and broke the earthen-ware pot, containing the mixture, into atoms, ſo that not the leaſt traces of it were to be found. [A]

† We have already pointed out the abſurdity of this idea. If a nitrous ſulphur can be ſaid to exiſt at all, it can be no other than nitrous gas: but this, beſides that it is not in the leaſt inflam-

becauſe at the very inſtant of its production, the matter of fire preſent in the nitrous acid, occaſions a conſiderable heat, ſufficient to kindle the ſulphur that is generated, and by this means at the ſame time to ſet the whole of the oil on fire. In thoſe caſes, however, in which experience has ſhewn an addition of concentrated vitriolic acid to be requiſite, in order to produce inflammations, the effect ſeems to depend upon this, viz. that this acid attracts part of the water which is an obſtacle to the attainment of the effect, and by this means promotes the combination of the phlogiſton of the oil with the concentrated nitrous acid, which may then be the eaſier inflammed by the matter of fire rendered active and heated.

Upon this depend chiefly the power and effects of the well-known *fulminating powder* (pulvis ſive nitrum fulminans) which is prepared merely by mixing together three parts of pure nitre, two of ſalt of tartar, and one of ſulphur. Any combuſtible matter, provided only it be capable of being totally converted into

inflammable, contains a ſmall quantity of air; whereas the genuine, or vitriolic ſulphur, has none. The true explication of the abovementioned fact ſeems to be as follows. The pure air of the nitrous acid being but looſely united with its baſe, is ſtrongly attracted by the vegetable baſe of the oil, while the phlogiſton is ſollicited, on the other hand, by that of the nitrous acid; the conſequence of which is, that a double decompoſition takes place; the air combining with the baſe of the oil ſeparates the phlogiſton; of which, part flies off in union with the mephitis of the nitrous acid, and a little air, in the form of nitrous gas; and the remainder (for oils contain much more than is ſufficient for this purpoſe) eſcapes in the form of light and heat. It ſhould likewiſe be obſerved, that part of the air of the nitrous acid is expended in ſeparating the phlogiſton from that portion of the inflammable gas of the oil which is volatilized, and with the hydrophloge of which it forms water. When eſſential oils are mixed with vitriolic acid, the air of the acid being ſtrongly united with its baſis, the decompoſition is not effected with ſufficient rapidity either to generate flame, or to volatilize the decompoſed parts. A little of the phlogiſton however combines with ſome part of the baſe of the acid not entirely deprived of its air, and flies off with it in the form of ſulphureous acid: that part of the air of the vitriolic acid which had parted with its ſulphureous baſe now uniting with the hydrophloge of the inflammable gas of which the phlogiſton had been volatilized, and forming water, as evidently appears from the analyſis of this mixture reported by M. *Macquer* in his Dictionary of Chemiſtry, under the article "Inflammation of Oils." According to the different nature of the oils employed, and to the different degrees of heat excited, the reſiduum after inflammation is either of a waxy, greaſy, or ſaponaceous nature, and more or leſs mixed with charcoal. [E]

vapour and accended, which yet is fixed in ſuch a manner, that its particles, expoſed to the action of the fire, cannot be ſeparated from each other otherwiſe than all at once, muſt neceſſarily be emancipated on this occaſion with a violent expanſive powder. In this ſeems to conſiſt the effect of the pulvis fulminans. When nitre and ſulphur only are mixed together and ſet fire to, the inflammation is carried on by the kindling of one part after the other in rapid ſucceſſion, ſomewhat in the manner of a detonation, but without any exploſion or report, when it is performed in the open air. But as ſoon as the ſalt of tartar is added, the peculiar fulminating effect takes place; hence its cauſe muſt neceſſarily proceed from the properties of the ſalt of tartar. When ſalt of tartar is fuſed with ſulphur, the former in ſome meaſure diminiſhes the inflammability of the latter by combining pretty intimately with the whole of the ſulphur, in conſequence of its attraction to both the conſtituent parts of this ſubſtance. Now as the inflammation of the fulminating powder, which is beſides obſtructed by the ſalt of tartar, is to be produced by the ſulphur, as being the only combuſtible ingredient that is preſent in this mixture, and even that in a ſmall quantity, the reaſon is evident, why this powder ought to be heated to a much greater degree than is otherwiſe requiſite for a mere mixture of nitre and ſulphur to be, when inflammation is expected to take place. In every caſe the nitre detonates with the ſulphur the inſtant the red heat commences, a circumſtance which ariſes from the action of the nitrous acid upon the phlogiſton of the ſulphur. Hence a nitrous ſulphur is produced, which on account of its great inflammability cannot ſtand the fire, and is therefore immediately deſtroyed by it. But as in this operation the water contained in the nitre is expelled at the ſame time, this, on the one hand, cauſes the noiſe, and, on the other, augments the elaſticity of the matter of fire. Now as in the compoſition of the pulvis fulminans, nitre, ſalt of tartar and ſulphur, act upon each other at one and the ſame time, and are put into motion by the external heat, while the ſalt-petre, for the reaſons mentioned above, cannot ſo readily deprive the ſulphur of its phlogiſton, as it does in other circumſtances, it being, on the other ſide, kept back by the ſalt of tartar, which manifeſtly prevents this action; all the parts of this compoſition conſequently muſt be the more heated, till at laſt by an extraordinary degree of heat, this action is annihilated, and all the beforementioned volatile particles break forth at once with an increaſed elaſtic force, which is accordingly accompanied with a report, and the diſperſion of the whole of the materials.

A ſimilar effect takes place in *fulminating gold* (aurum fulminans) which may be prepared chiefly in three different ways. The *Firſt Method* conſiſts in diſſolving gold in a menſtruum prepared with aqua fortis and ſal ammoniac, from which a precipitate is made with common alkali. In the *Second*, the ſolution of gold is precipitated from a menſtruum made of aqua fortis and uncombined marine acid. The *Third Mode* conſiſts in diſſolving gold in marine acid diſtilled from mangancſe, or what *Scheele* calls the dephlogiſticated marine acid, and precipitating it with volatile alkali. In all theſe caſes the precipitate obtained from it weighs commonly one fourth more than the gold uſed in the ſolution. The firſt deſcription of fulminating gold occurs in the writings of *Baſil Valentine*. The explication of its effects has ever ſince occupied the Chemiſts; but of all thoſe that have as yet appeared, I have found none perfectly ſatisfactory; from which ſentence I do not even except my own, which I inſerted in a Note upon *Vogel's* Inſtitutes of Chemiſtry. I have therefore revolved this operation in my mind afreſh; and have here committed to writing, what I think I have diſcovered concerning it. Perhaps an impartial judge will ſee as many errors in this, as in the preceding explications. Be it ſo; we have learned to walk by ſtumbling, and falſe judgments have frequently conducted us to the truth. Perhaps another, in conſequence of my error, will find the point of view, from whence he may diſcover more, and that more diſtinctly than I have been able to do.

The firſt circumſtance that ought to be conſidered in the propoſed *explication*, is the increaſe of weight of the precipitate. Nothing can be more certain than that here, as in all other precipitates prepared in a ſimilar manner, it proceeds from the ſaline particles both of the menſtruum and the precipitant, which intimately unite with the precipitated metal: A poſition that I am able to prove in the moſt ſatisfactory manner, in every caſe that can occur, and deſign ſhortly to prove in a Treatiſe written expreſsly on this ſubject. Beſides this alſo it cannot be denied, that in this operation at the ſame time a portion of air is developed from theſe ſaline ſubſtances, and united with the precipitated particles of the metal. Air, therefore, and ſome particles detached from the ſaline materials of the menſtruum and the precipitant, produce the increaſe of weight in the precipitated gold-powder, and in the very ſame circumſtances likewiſe muſt neceſſarily be enveloped the cauſe of its effects. But now we muſt examine farther what theſe detached ſubſtances are, that, beſides the air, are united to the gold-powder. It has been con-

ſtantly

ftantly oblerevd, that gold acquires for its folution a menftruum compounded of the nitrous and marine acids; and that for this purpofe it was indifferent, whether a quantity of fal ammoniac were diffolved in nitrous acid, or whether the pure marine acid were mixed with this latter. There was one circumftance, however, in which a difference was foon perceived, viz. That a folution of gold made with fixed alkali in the former method, yielded a fulminating gold-precipitate; and that, when the folution had been performed in the latter mode, volatile alkali muft neceffarily be taken for the precipitation, if the gold-powder was expected to have the fame property. Hence arofe the doctrine, that volatile alkali, whether contained in the menftruum or in the precipitant, was abfolutely requifite for the preparation of fulminating gold. Every difficulty now feemed to vanifh, as it was fuppofed, that in this inftance, by the volatile alkali, in conjunction with that portion of nitrous acid, which ftill remained in union with the gold-powder, a nitrum flammans was compofed, from which the fulminating powder of the gold-powder proceeded. This notion however is overturned at once, when we confider that in the third of the above-mentioned modes, a fulminating precipitate of gold may be obtained without nitrous acid. The nitrous acid therefore cannot by any means come under confideration on this occafion. On the other hand, the fufpicion, with refpect to the volatile alkali, becomes the ftronger, for the fubftance is neceffary, even in thofe cafes, in which no nitrous acid has been ufed. In whatever acid therefore gold is diffolved, either in the marine acid alone, or in this acid mixed with the nitrous, in every cafe, the volatile alkali muft be able to unite with the calx of gold to be precipitated by it, if it be expected to acquire the fulminating property. This is the abfolute and general condition, without which the property above-mentioned cannot be imparted to the calx of gold. But by this we have made the firft ftep only towards elucidating the points in queftion. We muft therefore go farther ftill, and, if poffible, difcover what the volatile alkali is combined with in the calx of gold. The third mode, mentioned above, plainly fhews that the marine acid, deprived of its phlogifton, is the true folvent of gold, and that, as has been long ago obferved by *Kunkel*, the ordinary marine acid requires but a fmall addition of nitrous acid, in order to diffolve gold; probably, merely on this account, that it muft be dephlogifticated by the nitrous acid. One muft neceffarily fuppofe, that the marine acid has a greater affinity to gold than nitrous acid, and alfo that it is, ftrictly fpeaking, the marine acid only that remains

remains combined with the precipitate of gold, and the volatile alkali, which at the ſame time attaches itſelf to the gold, is united with this acid. As clear proofs of this poſition, the following experiments, firſt made public by M. *Scheele*, deſerve attention. Thirty grains of a non-fulminating precipitate of gold, digeſted with ſal ammoniac, and edulcorated again, increaſed ſeven grains in weight, and then acquired the fulminating property. Likewiſe a non-fulminating precipitate of gold, digeſted with a ſolution of Glauber's ſal ammoniac, cauſed this ſolution to become acidulous, part of the volatile ſalt contained in it having united with the precipitate of gold, which by this means became fulminating. Whence, at the ſame time it is evident, that volatile alkali has a greater affinity with marine than with vitriolic acid. Finally, the ſame chemiſt mixed thirty grains of fulminating gold with three drachms of vitriolated tartar, and expoſed this mixture to the fire in a ſmall retort, by which means he obtained two grains of a ſublimate, which was nothing elſe than common ſal ammoniac. In the bladder, however, that was fixed to the neck of the retort, he collected phlogiſticated air impregnated with cauſtic volatile alkali.

The chemical conſtituent parts of fulminating gold therefore, as indicated by theſe experiments, are phlogiſticated, or perhaps inflammable, air, marine acid and volatile alkali, intimately united with the minute particles of the gold by precipitation. Thus far I have conducted my readers; but ſhould they now aſk me, how the fulminating effect is produced? I ſhall anſwer wihout heſitation, that this is all that I either know or am able to comprehend concerning the matter. Let it ſuffice, that here is the point in view, from whence theſe effects may be contemplated by every one that is inclined to employ his faculties upon a farther inveſtigation of the ſubject. It is to be preſumed that there ſubſiſts in the gold itſelf a cauſe of this effect, were it nothing elſe than a peculiarly modified attractive power with reſpect to the ſubſtances combined with this metal, by means of which the matter of fire contained in the gold, or that which ſubſiſts in the compoſition both of the marine acid and of the volatile alkaline ſalt, is ſet more at liberty than it was before; inſomuch that by a ſlight calefaction it is able to burſt forth on a ſudden, together with the air, and thus produce an exploſion and report *.

To

* It is to the genius and penetration of M. *Bertholet* that we are indebted for the explication of the principal circumſtances relative to this ſurpriſing phenomenon; though by rejecting the

To this head alſo may be referred the curious experiment made by Dr. *Higgins*, in which the cryſtals produced by the union of copper with the nitrous acid are triturated while they are in a moiſt ſtate, and ſtrewed upon tin foil to the thickneſs of the back part of the blade of a knife; then rolled up cloſe, the extremities of the foil pinched together, and the whole maſs preſſed down flat. In conſequence

the doctrine of phlogiſton, he has neceſſarily failed in the elucidation of ſome points, which ſtood in need of explanation.

The true theory of this proceſs appears to be as follows:—The earth of gold, precipitated in the methods above-mentioned from the nitrous or aerated marine acid, is united with pure air and volatile alkali. The earths of the noble metals having a very ſtrong attraction for phlogiſton, and a comparatively ſlight attraction for air, the earth of gold, while it attracts the phlogiſton of the volatile alkali, lets go the pure air, with which it was united, and which combining with the hydrophloge of the volatile alkali, forms water. This it can the more eaſily effect, on account of the union of the hydrophloge with the phlogiſton being weakened by the interpoſition of the mephitis, which is the third component principle of volatile alkali; and we may obſerve by the bye, that no other compound, containing either hydrophloge or inflammable gas has been hitherto found capable of reducing gold or ſilver in ſo low a degree of external heat. There is likewiſe a circumſtance in this experiment, that is always to be obſerved, though it has not been taken notice of by our author, which is an obſcure flaſh of light, at the inſtant that the reduction takes place, exactly ſimilar to the light yielded by inflammable gas, when it is ſet on fire on any other occaſion. This proceeds from the inflammable gas of the alkali being fired by the heat excited by the tranſition of the hydrophloge from an elaſtic to a fixed ſtate, and by combination of this latter principle with air; but is is only the ſuperfluous part of the phlogiſton that is thus diſſipated, the greater part paſſing over to the calx of gold, and reducing it. The exploſion proceeds from the velocity with which the external air is ſtruck by the almoſt inſtantaneous diſengagement of the mephitis contained in the volatile alkali.

But the abovementioned indefatigable and ingenious Philoſopher has lately diſcovered a ſtill more aſtoniſhing ſubſtance, which is announced in the Journal de Phyſique for June 1788, under the title of *Fulminating Silver*. It is prepared as follows:—Diſſolve cupelled ſilver in pure (or dephlogiſticated) nitrous acid. Precipitate the ſilver with lime-water, ; then decant the liquor and expoſe the precipitate for the ſpace of three days to the air. (M. *Berthollet* imagines, that at this period of the experiment the preſence of light may have an influence on its ſucceſs.) To this calx, when dry, add cauſtic volatile alkali: it will take the form of a black powder. Decant the liquor, and let the powder dry in the air. This is fulminating ſilver, which cannot bear even to be touched without fulminating: ſo that it muſt remain in the capſule in which it was dried. The volatile alkali too that has been employed in the preparation, being boiled in a thin matras, forms cryſtals, which upon being touched under the liquor with which they are are covered, ſuddenly detonate and break the matras in pieces. The explication of this phenomenon is the ſame as that of the former. In both, the detonation proceeds from a double decompoſition. [E]

of

of this heat is produced, and at length follows a detonation accompanied with flame. In this operation the phlogiſton of the tin is thrown into an inteſtine motion by the action of the concentrated nitrous acid contained in the ſalt of copper and ſet at liberty; by which means the ſalt of copper (which, without this addition, of itſelf is inflammable) is the eaſier heated and inflamed; though for this purpoſe there is no neceſſity for the application of heat ab extra, which, on the contrary, is requiſite, when lead diſſolved in nitrous acid and cryſtallized, is to be made to deflagrate in a ſimilar manner.

CHAP

# CHAP. V.

## WATER.

HAVING now diſpatched the firſt of the phyſical elements, called *Fire*, we muſt beg leave to refer the reader to the introductory part of this Treatiſe for thoſe of *air* and *earth*, and to conclude theſe fragments of philoſophical chemiſtry with ſome neceſſary diſquiſitions on the remaining element (as it is called) *Water*; and particularly with an analyſis of mineral waters, taken from a Paper publiſhed ſome time ago by Dr. *Struve* in the *Memoires de Lauſanne*.

*Water* poſſeſſes an uncommonly great *diſſolving power*; great, by the inceſſant mechaniſm of nature, and thus efficacious with reſpect to bodies upon which art employs its power in vain. For bodies are ſometimes found to be united with water, (or at leaſt we have every reaſon to believe that they have been united with water) which we never can combine with it in the ſame manner as nature does. On account of this its great diſſolving power, we may with confidence affirm, that, ſtrictly ſpeaking, no ſuch thing as pure water is to be met with in nature; it is every where impregnated with various foreign ſubſtances, only in ſome places more than in others. Hence proceeds the difference obſerved long ſince, between ſnow-rain- dew- ſpring- river- and ſea-water, and in like manner between other waters, called mineral waters, of which it is the province of the chemiſt to give an account.

From theſe the water, which is contained in the atmoſphere, and thence comes again to the earth, differs in various degrees of purity. Of this the pureſt is that, which exhales from the earth and the bodies on its ſurface, with the gentleſt heat, and is diſſolved by the air; hence *ſnow-water* muſt neceſſarily be

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deemed the pureſt of all. And as, on the other hand, in warm weather the earth together with all the creatures ſubſiſting on its ſurface, exhale into the air a greater number of volatile particles, it is eaſy to conceive, that *rain-water* muſt be much more impure than this. In caſe ſnow- or rain-water is wanted, it muſt be collected immediately from the air; it is alſo adviſeable not to collect it till after it has ſnowed or rained for the ſpace of an hour. For this purpoſe large glaſs or earthen veſſels, well glazed, are neceſſary; the uſe of veſſels made of metal or wood muſt be avoided. In this manner is obtained from the great ſtorehouſe of nature the pureſt water, which however is very ſeldom conſidered as ſuch by the chemiſt. For though theſe waters have undergone a real diſtillation, and likewiſe cannot eaſily be ſuppoſed to be mixed with groſs earthy particles, they may nevertheleſs contain ſome volatile parts, which muſt certainly be conſidered as foreign to them. On this account it is neceſſary, in nice chemical experiments, to diſtill afreſh waters collected in this manner, in new and clean glaſs veſſels by a gentle heat; and at the ſame time care ſhould be taken, in caſe they ſhould be contaminated by ſome volatile particles in them, to retain theſe particles in the reſiduum, by means of certain additaments. Water diſtilled in this manner with the utmoſt precaution, is then deemed perfectly pure, when it does not render the ſolution of ſilver or lead in nitrous acid turbid, upon one or two drops being mixed in an ounce of the water. *Rain-water*, that falls in very hot weather, muſt, for the reaſons abovementioned, be neceſſarily ſtill more impregnated with foreign particles. Hence too, the water of *thunder-ſhowers* is impure. Here in particular, the electric matter, which is conducted from the clouds to the earth, muſt be attended to *. Upon this depends its fertilizing power, which has been long ſince obſerved in it. The tales concerning *ſulphureous rains*, are without any other foundation than this, that in high winds, the ſeeds of the burdock, and the farina of the bloſſoms of the fir-tree, are carried aloft in the air, and fall in ſome other place. *Bloody-rain*, which excites ſo much terror in the ignorant and ſimple, is cauſed by the caterpillars that at the end of June, and beginning of July, come forth from their larvæ, ſwarm in the air, and ſometimes let fall ſome drops of a reddiſh liquor. The *Dew*, which in the morning and even-

* This conſideration is futile and ſuperfluous; the reaſon given juſt before, being quite ſufficient. [E]

ing is found upon graſs and other low vegetables, is nothing but the vapour of the earth, condenſed on the blades of graſs and leaves of different plants. It would be ſtrange indeed to expect more from it, than from common rain-water, or to make ſuch preparations for collecting it as have already thrown a ridicule upon many, who have thought to intercept in this manner the ſpirit of the univerſe, a ſpirit exiſting only in their imaginations.

We obtain the greateſt quantity of water for drinking and other uſes by means of *ſprings* from the boſom of the earth. Theſe have their origin from the water of the atmoſphere; rain, ſnow, fogs and all vapours in general are the principal cauſes of ſprings, wells, and rivers. Of theſe ſprings a great number ariſe from ſuch waters as occur on on more elevated places, thence penetrating into the earth, are carried through the ſtrata of ſand, and purified in them, till at length they find an iſſue by the ſuperior ſtrata of clay, when they commonly bring with them ſome quartzoſe ſand beſides. The ſmaller and leſs conſiderable ſprings ſeem to ariſe in many places, merely from a gradually ſucceſſive accumulation of rain-water or of melted ſnow and ice in places where they are prevented from penetrating farther into the earth by ſtrata of clay. Hence too they do not conſtantly flow, are frequently dried up in great droughts, and re-appear only after a long continuance of wet weather. High mountains in all probability contribute the moſt to the maintenance of flowing waters; for theſe large maſſes of earth, which project ſo high up into the atmoſphere, and whoſe ſummits, for the greateſt part of the year, are frequently covered with ſnow and ice, which upon ſome are to be ſeen the whole year round, theſe huge bodies, I ſay, inſtantly attract and abſorb the vapours, which, independently of this cauſe, are ſufficiently condenſed in theſe cold regions. The liquid water, which is gradually encreaſed by the melting of the ſnow and ice, runs down from their ſummits, and is commonly collected at the foot of the mountain or in low plains, and forms conſtantly flowing ſprings. In this manner part of the *Rhine* has its ſource upon mount Gothard in Switzerland, and another part is collected from one of the Glacieres or icy mountains; theſe too are formed in the *Mayne* upon the *Fichtelberg* in Franconia; and the *Elbe* in the diſtrict of Bunzlaw in Bohemia, near the Rieſengebirge or Giants' mountains, upon the frontiers of Sileſia.

Water, in conſequence of its diſſolving power, when it has run through the earth, in the various ways above-mentioned, and according to the difference of

its origin and ſource, when it riſes again in the form of ſpring-water, muſt be of a very different nature, according to the different ſoluble ſubſtances it has met with in its way, and which have entered into union with it. Thus *brine-ſprings* will be formed, when a body of pure water ſtrays into places, where common ſalt is accumulated in the earth. Other waters, that run a long way over ſtrata of clay and Gypſum, are entirely loaded with theſe ſubſtances, inſomuch that they acquire what is called a petrifying property. This ſolution takes place in different proportions; ſo that even the pureſt potable ſpring waters are not totally free from this earthy mixture. The greater the proportion is of theſe diſſolved ſubſtances, the worſe the water is deemed, and the leſs uſeful alſo it is found in many reſpects. Many waters of this kind are by nature abſolutely unfit for brewing, dying, waſhing, or bleaching, and in general, for every purpoſe where they muſt act by their diſſolving power. Theſe ſorts of water are called *hard waters*, and are known in common life by the property they have of preventing the lathering of ſoap, and by their incapacity to boil ſoft any kind of pulſe. The gardeners call them *cold waters*, becauſe the plants, that are watered with them, do not thrive ſo well as they do with ſoft water. Theſe natural defects however may be removed by the aſſiſtance of art. Sometimes it will be ſufficient to expoſe them for the ſpace of ſome days to the open air and the ſun; but ſometimes it is neceſſary to boil them before they are uſed; where however this does not ſufficiently anſwer the intention, or where it cannot be done, a ſmall addition of alkali will produce the melioration deſired.

And indeed, all that art can effect in this way upon thoſe hard waters, is done by nature herſelf: viz. When theſe ſpring waters flow in an open river for a conſiderable ſpace, they gradually loſe, by the evaporation of their volatile parts, the power of retaining theſe extraneous earthy particles any longer in ſolution; or elſe the combination of theſe ſubſtances with the water is deſtroyed by the fortuitous acceſſion of the alkaline ſalts of putrified vegetables and animal bodies that are never wanting in river water; upon which alſo is founded the practice of the Gardeners, who by way of correcting theſe hard waters, throw a little dung into them. By this means they loſe their earthy particles and become ſoft. Whence, commonly, the waters of rivers, ponds and freſh water-lakes are found to be ſoft, if their beds do not conſiſt of a mere argillaceous, ſchiſtous or gypſeous compound.

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*The Water of the Sea* is salt in every part of the world; and has withal a bitter disagreeable taste, of which the reason is to be sought for in its *constituent parts*. Of these the greatest part is composed by salts; which however are mixed with all sorts of impurities, arising from the great number of fishes, insects, and other animals, as well as of plants, plants which are generated, live, die, and are dissolved in it by putrefaction. It does not however contain the same quantity of salt in every region of the globe; but the quantity of salt contained in it, differs according to the nature of the place. It is a general rule, that the hotter the region, the more salt there is contained in the sea. In the Spanish sea, and the Mediterranean, a pound of water commonly contains an ounce of salt; in the German ocean, from the mouth of the Elbe to Holland, and in the Channel between Holland and England, half an ounce only; and in the northern part of the Baltic, scarcely a quarter of an ounce*. In the proportion of the salt as given by

* Our knowledge of this subject has been greatly extended by the experiments made by Lord *Mulgrave*, in the course of a voyage towards the North Pole. The sea-water at the *Nore* he found to contain not quite $\frac{1}{30}$ of salt; at the back of *Yarmouth* sands, not quite $\frac{1}{32}$; off *Flamborough Head*, rather more than $\frac{1}{29}$; off *Shetland*, rather less than $\frac{1}{29}$; in lat. 74 at sea, $\frac{1}{29}$; lat. 78, less than $\frac{1}{28}$; in lat. 80 near the ice, not quite $\frac{1}{30}$; in lat. 80. 30, under the ice, not quite $\frac{1}{28}$; in lat. 68. 46, rather more than $\frac{1}{28}$; in lat. 65 at sea, rather less than $\frac{1}{25}$. See a Voyage to the North Pole, 1773, by *Const. John Phipps*, p. 143. Dr. *Hales* got only $\frac{1}{27}$ from the sea-water of the Mediterranean, and $\frac{1}{29}$ from water taken up at the *Nore*. Dr. *Rutty* says that he obtained from sea-water taken up in lat. 65, $\frac{1}{25}$; $\frac{1}{28}$ from the sea near Dublin, and $\frac{1}{30}$ from water taken up at Dungarvan, and Dr. *Lucas*, that he obtained $\frac{1}{15}$ from the sea-water in the vicinity of Harwich. *Monro* on Mineral Waters, Vol. I, p. 105.

It appears from some experiments formerly made in a voyage from England to Bombay, that the weight of the sea water was the greatest, not precisely at the Equator, but where the sun was vertical, and consequently, in similar circumstances, where the heat was greatest.

The greatest weight of a definite quantity of sea-water which was observed in sailing from 28 degrees N. lat. to the Cape of Good Hope, which is about $34\frac{1}{2}$ deg. S. lat. in the months of May, June and July, was at St. Jago island, N. lat. 15 degrees; and the least was at Teneriffe island, N. lat. 28. The weights of equal bulks of Thames water, of the sea-water off Teneriffe and St. Jago, were 659,—$673\frac{1}{2}$, $780\frac{1}{2}$ grains, Gent. Magaz. Vol. XXV. p. 260, whence it may be concluded that the Teneriffe sea-water contained about $\frac{1}{32}$ of salt, and the St. Jago water above $\frac{1}{4}$ of its weight of salt, Bp. *Watson's* Chemical Essays.

There are some very accurate experiments on the subject of the different gravity of the water of the sea in different parts, made by *Peter John Bladh*, a Swede, and related by him in the *Kongkl. Wet. Acad. Nya Kandlingar*, for 1781, Part II, page 108—126, where the reader will find a great many observations couched in the form of Tables. However, as the limits of this volume will not allow room for the insertion of a translation at full length, I shall only give the conclusions deduced from his experiments.

I. He

by the writers, who have themſelves made experiments upon this ſubject, there is a great difference found, which may ariſe from the circumſtance of one having made his experiments at one time of the year, and another at another. One, that may have made them in a hot Summer, may probably have found the ſea water more abounding in ſalt at that time, than another who performed this operation in the Spring, or Autumn; for the ſea in a greater heat loſing more of its mere watery parts by evaporation than in cooler ſeaſons of the year, it muſt alſo contain more ſalt in the former than in the latter ſeaſon. The water of the ſea has alſo been found by experience to contain more ſalt near the bottom than at the upper part, undoubtedly for this reaſon, that at the ſurface it is continually

I. He found the ſea-water neareſt to the Tropics in the Atlantic and Æthiopic Oceans to be the heavieſt; its ſpecific gravity at the temperature of 68 degrees above 0, being from 1,0280, to 1,0283.

II. That its ſpecific gravity decreaſes from the tropics, as well towards the Pole as towards the Equator, and this even in ſo high a latitude as that in which the experiments were made.

III. That the lighteſt water between the tropics is not much heavier than the water of the North Sea; its ſpecific gravy being not above 1,0262 and 1,0264. This lightneſs of the water under the Equator may proceed from hence, that all the watery vapours which ariſe from the whole ſurface of the ſea in the torrid zone, are carried towards the Equator by the continual winds that prevail there, and fall down in the form of rain. As alſo in the parts of the Atlantic and Æthiopic oceans that are ſubject to the conſtant winds, the water is commonly heavieſt, where the Trade-wind blows briſker, but becomes lighter towards the Equator, in proportion as the wind is milder, till about the third degree north latitude, at the boundaries at which both Trade-winds meet, and where the water is lighteſt.

IV. That the water is not quite the lighteſt under the Equator; neither is it heavieſt under the Tropics, but that the whole current in this ocean ſets a few degrees towards the north. The caſe is the ſame with the winds, for the north-eaſt wind extends generally in a higher latitude to the north of the Equator, than the ſouth-eaſt to the ſouthwards.

V. That the heavieſt as well as the lighteſt water which lies between it, does not run parallel to the Equator, but, on the African coaſt turns a little towards the north, and, on the American, towards the ſouth.

VI. That the heavieſt water in the Indian ſea, of which the ſpecific gravity amounts to no more than about 1,0272 and 1,0274, is found, it is true, in the vicinity of the ſouthern tropic; but yet it is ſtill more to the ſouth than in the Æthiopic, and the trifling declination it makes from the Equator ſeems to be oppoſite to the laws it obſerves in the Æthiopic.

diluted by torrents of rain and ſnow, and by the rivers running into the ſea, which carry freſh water into it*. The ſaline compound contained in ſea-water, conſiſts chiefly of common ſalt. *Gaubius* found by experiment that a pound of ſea-water taken up from the North Sea on the coaſt of Holland, contained three drachms and ſeventeen grains of common ſalt, twenty-four grains of Glauber's, and ten grains of an earthy neutral ſalt, which was partly of a ſelenitic nature, and partly conſiſted of magneſia combined with marine acid. Beſides this, it is certain that genuine Epſom ſalt is found in it. From this latter ingredient proceeds its bitter

VII. The mean of the ſpecific gravity of the Sea-water at the temperature of 68° above o is,

| | North Lat. |
|---|---|
| In the Atlantic between 35° and the Equator, in the voyage thither, - | 1,0272,6. |
| On the return, - - - - - - - - - | 1,0276. |
| In the Æthiopic ocean between the Equator and lat. 35°, upon the voyage, - | 1,0273,5. |
| Upon the return, - - - - - - | 1,0274,9. |
| In the Indian ſea between the Cape of Good Hope and Java, upon the voyage and return, | 1,0266. |
| In the Chineſe ſea between the Equator and the Chineſe coaſt, upon the voyage and return, | 1,0250,5. |

The difference of the gravity of the water of the Atlantic, obſerved upon the voyage and on the return, chiefly proceeded from their having ſailed on the voyage thither a few degrees only from the African coaſt, whereas on the return they ſailed nearly in the middle of that ocean.

VIII. Hence it appears that the water of the ſea is commonly lighter near land than it is at a diſtance from ſhore, and in the middle of the ſea. [D]

* Though this reaſon has been ſuppoſed by the Count *Marſigli* and other able Philoſophers, it is only the caſe after a long rain, and with the water which has an immediate communication with large rivers; but in hot weather, when of courſe the temperature of the ſurface of the water is much higher, and a large quantity of water is continually evaporating, the water of the ſurface muſt undoubtedly contain more ſalt than that of the depth, and of a lower temperature. This reaſoning is founded on the following experiments mentioned by Lord *Mulgrave*, in his *Voyage towards the North Pole.* "In the open ſea off Shetland, ſays his Lordſhip, in 60 deg. N. lat. equal quantities of water were taken up nearly at the ſurface, and at the depth of fifty-five fathoms; theſe different waters yielded by evaporation equal quantities of ſalt, namely, $\frac{1}{29}$ of their weight nearly. On another occaſion, in north lat. 65 deg. ſome water taken up from the ſurface, gave nearly $\frac{1}{28}$ of its weight of ſalt; whilſt an equal weight taken up from the depth of 683 fathoms in the ſame place, gave only $\frac{1}{32}$."

M. *Bladh* infers from his numerous experiments, that there is little or no difference between the ſpecific gravity of ſea-water taken out of the *Atlantic*, at the depth of fifty fathoms, and of that which is taken from the ſurface; or at leaſt this difference is not certain and conſtant. It is therefore highly probable, ſays he, that there is no material difference in the degree of ſaltneſs

bitter taſte, by many attributed to the preſence of a bituminous ſubſtance, but of which *Gaubius* did not diſcover the leaſt veſtige. From the nature of theſe conſtituent parts the difficulty of rendering ſea-water drinkable, is evident; for even if by all the different modes of filtration that can be deviſed, the earthy and other groſſer compounds could be ſeparated from it, the pure neutral ſaline compounds would ſtill remain in it. The beſt way of purifying it therefore will probably ſtill continue to be by filtration, for which purpoſe, M. *Poiſſonier*, in the year 1763, publiſhed his invention of a convenient diſtilling apparatus, the chief object of which was, on the one hand, the ſaving of fire, and, on the other, convenience; an invention of which *Beaumé* † has given the deſcription. Beſides

ſaltneſs of the ſea at theſe different depths: and Dr. *Sparrman's* experiments which ſeem to prove that there is, are (though quoted by *Bergmann*) not to be depended upon, as being very far from accurate, and not being made in favourable circumſtances. [E]

* *Bergman* in his *Eſſays Phyſical and Chemical*, p. 116, ſays that ſea-water contains ſalt, vitriolated and ſalited Magneſia, gypſum, and a conſiderable quantity of putrid extractive matter: but at page 230 (of the Engliſh Tranſlation) he gives the following as the contents of a kanne, i. e. about three quarts, of ſea-water taken up by Dr. *Sparrman* from the depth of 60 fathoms near the Canary Iſlands, together with an almoſt imperceptible quantity of aerated magneſia.

| | *Oz.* | *Gr.* |
|---|---|---|
| Common Salt - - - - - | 2 | 433 |
| Salited Magneſia - - - - | 0 | 380 |
| Gypſum - - - - - - | 0 | 45 |

It may be obſerved that the vitriolated magneſia, or ſal catharticus amarus is here wanting. As for the abſence of putrid extractive matter, *Bergman* ſuppoſes it to be found near the ſurface only, and that it is generated by the putrefaction of fiſh, inſects and vegetables. Hence he takes occaſion to ſuggeſt to mariners that advantage of uſing ſea-water taken up at the depth of 60 fathoms or more, and diluted with an equal quantity of freſh water, for boiling proviſions on board of ſhip; and thus ſaving half their freſh water. [E]

† In his *Chemie Experimentale & raiſonnée*, Tom. III, p. 576 & ſeq.

This method has been ſo much improved by Dr. *Irving*, that he ſeems to have been juſtly entitled to the Parliamentary reward of Five Thouſand Pounds, which he has obtained. In this method, according to the Teſtimony of the Officers who were eye witneſſes to an experiment made on board the Arrogant, at Spithead, 1771, 500 hundred gallons of freſh water may be diſtilled in the courſe of twenty-four hours, with the ſame quantity of fuel in proportion to the time as is required in the ordinary buſineſs of the ſhip. Every ſhip's kettle is divided into two parts, by a partition in the middle: one of theſe parts is only in uſe when peaſe, or oatmeal are

Besides this, Captain *Cook* has observed that, sea-water may be rendered drinkable by freezing*. There has been no possibility as yet of attaining any certainty with respect to the cause of the saltness of sea-water; hence the opinions of Naturalists are still very different upon this subject. If the sea was not salt ab origine, the contrary of which has not, to my knowledge at least, been proved; the question naturally occurs, by what means did it become so? If it could be proved, that the saltness of it is not original, but has arisen in process of time, the circumstance might be deserving of an investigation, which however has not hitherto been attended with the least success.

Some suppose that its saline quality has been gradually produced from the phlogiston of the inexpressible quantity of organized bodies that are generated in the sea, and perish there by the continued action of the sun-beams upon them. This assertion, as well as the other, that its saltness originates from the solution of the salt that is to be found in immense quantities in various parts of the earth, or from salt-banks that are supposed to be at the bottom of the sea, has very great difficulties opposed to it. Upon the former supposition, many lakes which likewise contain a great number of organized bodies, and are in like manner exposed to the rays of the sun, and nevertheless do not contain salt-water, prove to the contrary. The same may be said of many stagnated ponds and marshes. Upon the latter supposition, the sea must continually grow salter and salter, which is not the case. It may therefore be supposed with more probability as well as

are dressed; but water is at the same time kept in the other to preserve its bottom. Dr. *Irving* has availed himself of this circumstance, and by filling the spare part of the copper with sea-water, and fitting on the lid and tube, he has shewn that sixty gallons of fresh water may be drawn off during the boiling of either of those abovementioned provisions, without the use of any additional fuel: he recommends also the preserving the water which may be distilled from the coppers in which pease, oatmeal, or pudding, are dressing, as both a salutary beverage for the scorbutic, and the most proper kind of water for boiling salt provisions.

Bp. *Watson* having examined this distilled sea-water, found it not entirely free from saline particles; though it contained them in so small a proportion as not to injure its salubrity in any sensible degree. (Dr. *Watson's* Chemical Essays, Vol. II, p. 172.)

* That the water of the flakes of ice floating in the sea is fresh and drinkable, has been advanced long ago by *Bartholinus*, in his Treatise *de Nivis Usu*, cap. IV, page 42, and *Boyle*, in his *Experiments and Observations touching Cold*, page 59, says, that the brewers at Amsterdam, a long time since used the ice-water of the sea for brewing. But to this head chiefly appertains *Sam. Reyheri Experimentum novum, quo aquæ marinæ dulcedo examinata describitur.* [A]

 more

more naturally, that the ſea from the time it was ſeparated from the earth, and incloſed within its boundaries, has been ſalt in the ſame degree as it is now, and that ſo it ever will remain, and that all *rivers* have gradually only ariſen from the water exhaled from it. All the freſh water that it daily and hourly loſes by evaporation, is reſtored to it again by rain, ſnow, and the rivers that empty themſelves into it; it therefore continues to be always of one and the ſame degree of ſaltneſs. Beſides, how could the inhabitants of the ſea have lived firſt in freſh, and afterwards in ſalt-water? Perhaps too, its poſſeſſing this ſaline property proceeds from a particular proviſion of the great Creator of the univerſe, otherwiſe, a water impregnated with ſuch a vaſt variety of animal and vegetable ſubſtances in thoſe hot regions, would ſoon paſs over into an intolerable ſtate of putrefaction, and fruſtrate the great uſe of the ſea for the purpoſes of commerce.

CHAP.

# CHAP VII.

## Of the ANALYSIS of MINERAL WATERS.

### SECT. I. Of the ſimple INVESTIGATION of MINERAL WATERS.

THE topography of the place where theſe waters riſe, is the firſt thing to be conſidered. By examining the ooze formed by them, and the earth or ſtones through which they are ſtrained and filtered, ſome judgment may be formed of their contents. In filtering through the earth, and meandering on its ſurface, they take with them particles of various kinds, which their extreme attenuation renders capable of being ſuſpended in the fluid that ſerves for their vehicle. Hence we ſhall ſometimes find in theſe waters, ſiliceous, calcareous, or argillaceous earth, and at other times, though leſs frequently, ſulphur, murioecic earth, or, from the decompoſition of martial aerocrate ochre. Thus Count *Razoumowſki* found, that the tepid ſpring at Loeſch in the Vallais in Switzerland, contained iron impregnated with fixed air; but that this martial aerocrate being very eaſily decompoſed, by reaſon of the warmth of the water, remained ſuſpended by means of the inteſtine motion occaſioned by this warmth, and turned the ſilver that was plunged into it, yellow. Beſides the ſubſtances abovementioned, mineral waters contain many others actually diſſolved in them, in abundance, viz. aerial acid or fixed air, mineral alkali, Glauber's ſalt, calcareous and murioecic earth, ſelenite, calcareous nitre, murioecic vitriol, alum, aerocrate of iron, martial vitriol combined with iron more or leſs dephlogiſticated, combinations of iron with the muriatic acid, liver of ſulphur, hepatic gas; and, finally, extractive matter,

furnifhed by the bog through which they are ftrained, before they emerge into the air in the form of fprings. Vitriol of copper is feldom found in mineral waters; it is only in the fubterraneous waters which flow over copper ores, that fome flight veftiges of it are found. Sedative falt has hitherto been found in the water of the Lake of Monterotondo only. Arfenic is ftill rarer, though the ancient chymifts pretended to have found it in many mineral waters. Inflammable gas, being generally the product of putrefaction, is feldom found in fpring waters; and though it is often met with in ftill waters, that ftagnate on the furface of the morafs, it occurs but very feldom in the fpring itfelf. So likewife the vegetable alkali, being produced by the decompofition of vegetables, is merely an adventitious ingredient in fpring waters. The cafe is the fame with refpect to vitriolated tartar and nitre; the laft however occurs more frequently than other matters. Volatile alkali being produced chiefly by the decompofition of animal fubftances, is ftill feldomer met with. It is but of late that terra ponderofa, magnefia, and the different combinations of thefe fubftances have been found in mineral waters.

Laftly, as the acids always tend to combine with other fubftances, it is hardly poffible to find them here in an uncombined ftate.

From this fynoptical view of the different ingredients contained in mineral waters, it is evident, that thefe fubftances occur in two different diftinct ftates, viz: 1. As being fufpended in them: and, 2. as being diffolved in them in the form of a falt.

The inveftigation of mineral waters confifts: 1. In the examination of them by the Senfes: 2. in the examination of them by Re-agents: 3. in the Analyfis properly fo called.

## Examination by the Senses.

(a) The appearance of the water, the inftant in which it is pumped out of the well, as well as after it has ftood for fome time, affords feveral indications, from which we are enabled to form a judgment concerning its contents. If the water is turbid at the well, the fubftances are fufpended only, and not diffolved; but

but if the water is clear and tranſparent at the well, and ſome time intervenes before it becomes turbid, the contents are diſſolved by means of fixed air.

The preſence of this gas is indicated likewiſe by ſmall bubbles that riſe from the bottom of the well, and burſt in the air while they are making their eſcape, though the water at the ſame time perhaps has not an acid taſte. This is the caſe, according to Count *Razoumowſki*, with reſpect to the tepid ſpring in Vallais, and the cold vitriolated chalybeate ſprings at Aſtracan. But the moſt evident proof of a ſpring containing fixed air, is the generation of bubbles on the water being ſhaken, and their burſting with more or leſs noiſe, while the air is making its eſcape.

The ſediment depoſited by the water in the well is likewiſe to be examined; if it be yellow, it indicates the preſence of iron; if black, that of iron combined with ſulphur; but chalybeate waters being ſeldom ſulphurated, the latter occurs very rarely. As to the colour of the water itſelf, there are few inſtances where this can give any indication of its contents, as there are not many ſubſtances that colour it.

(*b*) The odour of the water ſerves chiefly to diſcover the preſence of ſulphur in it: ſuch waters as contain this ſubſtance, ſmell of liver of ſulphur, or rotten eggs.

(*c*) The taſte of a ſpring, provided it be perfectly aſcertained by repeated trials, may afford ſome uſeful indications with reſpect to the contents. It may be made very ſenſible by taſting water, in which the various ſalts that are uſually found in ſuch waters, are diſſolved in various proportions. There is no certain dependence however to be placed on this mode of inveſtigation; for, in many ſprings, the taſte of Glauber's ſalt is diſguiſed by that of the ſea-ſalt united with it. The water too, it muſt be remarked, is not only to be taſted at the ſpring, but after it has ſtood for ſome time. This precaution muſt be particularly obſerved, with reſpect to ſuch waters as are impregnated with fixed air; for the other ſubſtances contained in them make no impreſſion on the tongue, till the fixed air has made its eſcape; and it is for the ſame reaſon that theſe waters muſt be evaporated in part, and then taſted again.

Though the ſpecific gravity of any water contributes but very little towards determining its contents, ſtill it may not be entirely uſeleſs to know the ſpecific weight of the water, the ſituation of the ſpring, and the kind of ſediment depoſed by it.

EXAMINA-

## EXAMINATION of the WATERS by MEANS of REAGENTS.

IT is abſolutely neceſſary to make the experiment with water juſt taken up from the ſpring, and afterwards with ſuch as has been expoſed for ſome hours to the open air; and ſometimes a third eſſay is to be made with a portion of the water that has been boiled, and afterwards filtered. If the water contains but few ſaline particles, it muſt be evaporated; as even the moſt ſenſible reagents, ſuch as the ſolution of ſilver, and the ſalts found by the union of the terra ponderoſa with the nitrous and muriatic acids, do not in the leaſt affect it; if the ſalt, whoſe preſence is to be diſcovered by them, are diluted with too great a quantity of water. Now, it may happen, that a water ſhall be impregnated with a conſiderable number of ſaline particles of different kinds; though ſome of them may be preſent in too ſmall a quantity; for which reaſon the water muſt be examined a ſecond time, after having been boiled down to three fourths.

The ſubſtances, of which preſence is diſcoverable by reagents, are

A. Alkalies and Earths combined with aerial acid.

Paper ſtained with Brazil wood, will diſcover the preſence of theſe ſubſtances in the water: if the water contains the ſmalleſt portion of alkali, they will change its red hue into a colour partaking more or leſs of the violet. A ſtill greater degree of ſenſibility is ſhewn, according to Mr. *Watts*'s experiments, by the tincture of the leaves of the braſſica rubra, as well as by that of roſe leaves.

(*a*) Alkaline Salts.

The taſte is ſometimes ſufficient to indicate their preſence in mineral waters impregnated with aerial acid; after theſe waters have been expoſed to the air for ſome time; but for the ſake of producing abſolute conviction, let a paper ſtained with turmeric be dipped in the water previouſly warmed, the colour of this is changed by alkaline ſalts only, and not by earths; now if the colour of the paper is changed, and a quantity of ſal ammoniac put into the water produces a ſmell of volatile alkali, the water certainly contains fixed alkali.

(*b*) Abſorbent

(*b*) Abſorbent earths.

Water which does not change the colour of paper ſtained with Brazil wood or Litmus, and which, after having been boiled, does not render lime-water turbid, contains abſorbent earth; if this earth be of a calcareous nature, it will be precipitated by the acid of ſugar, provided the water be taken freſh from the pump: but not after it has been boiled, unleſs indeed a particle or two of this earth ſhould be diſſolved in another acid, but in this caſe the ſediment will not be nearly ſo conſiderable as in the other. The caſe is the ſame with reſpect to barytes or terra ponderoſa.

(*c*) A mixture of alkaline ſalts and earth.

The water having been examined in the above-mentioned method for the purpoſe of diſcovering the alkaline ſalt in it, let part of this water be made warm; if it becomes turbid, there is certainly, excluſively of the alkali, an earth diſſolved in it by means of fixed air. I forbear to ſpeak here of the earth when in combination with the alkali.

B. Neutral ſalts in general.

The pureſt vinous ſpirit ſerves to diſcover their preſence; but for the ſake of aſcertaining that the ſubſtance precipitated by it, is a ſalt perfectly neutralized, the water muſt be filtered, as ſoon as this ſubſtance has ſettled, and when the ſpirit is evaporated, the reſiduum muſt be taſted; the taſte will be ſufficient to direct the experimenter with reſpect to the choice of his reagents.

(*a*) Vitriolic ſalts in general.

A few drops of the ſolution of terra ponderoſa in the muriatic acid, will be ſufficient to diſcover the ſmalleſt particle of any vitriolic ſalt; the acid of which will fall down combined with the terra ponderoſa in the baro-ſelinite, or barytic vitriol.

(*b*) Muriatic ſalts in general.

Waters containing theſe ſalts, throw down from a ſolution of ſilver in nitrous acid, a white precipitate, (luna cornea) which is inſoluble in nitrous acid.

(*c*) A mixture of muriatic and vitriolic ſalts.

Firſt, let a ſolution of the terra ponderoſa in nitrous acid be poured into the water till nothing more be precipitated from it; the precipitate being ſeparated, let a ſolution of ſilver be poured into the filtered liquor, till it ceaſes to yield any precipitation. The former of theſe precipitates indicates the preſence of vitriolic, the ſecond that of muriatic ſalts; and the difference in the quan-

tity

tity of the fediments, fhews the different proportion of thefe fubftances in the water.

C. Earthy Salts.

Alkali, faturated with fixed air, precipitates the earth out of all earthy and metallic falts. But to know whether this precipitate be of a metallic, or merely of an earthy nature, the experiment muft be made with the Pruffian alkali. If this throws down no precipitate, the former fediment was mere earth.

(*a*) Calcareous Salts.

A few grains of the acid of fugar will difcover thefe falts, provided that the water, containing them, has been previoufly boiled; if a precipitate is formed, there is no doubt of their prefence.

(*b*) A mixture of abforbent calcareous earth and calcareous falts.

In order to afcertain their prefence, the water muft be boiled; if during the boiling an earth is thrown down, which after having diffolved in the acetous acid, forms a precipitate with the acid of fugar, and if the water yields at the fpring a ftill greater fediment with the acid of fugar, it contains, befides a calcareous falt, a portion of calcareous earth.

(*c*) A mixture of calcareous earth with falts, in which another earth is contained.

Let a fmall quantity of a folution of acid of fugar be poured into the water; if it contains calcareous earth, a precipitation will enfue. To the fuperincumbent water after it has been decanted off from the earth and filtered, a folution of alkali faturated with fixed air, muft be added. If another precipitation enfues, there is, befides the calcareous earth, another earthy falt in the water. For the purpofe of difcovering it, a little diluted acid of vitriol muft be poured upon the precipitate, which without caufing any effervefcence, will form Epfom falt, if the precipitate be muriatic earth; regenerated heavy fpar, if it be terra ponderofa; and alum, if it confifts of alumite, or earth of alum.

(*d*) Barytic Muria and Barytic Aerocrate.

If the water be fuppofed to contain at the fame time terra ponderofa combined with fixed air, and the fame earth in a perfectly faline ftate; means muft be ufed analogous to thofe that are employed for the difcovery of calcareous earth; which is, to boil the water; to diffolve the earth which precipitates, in the marine acid; and then try whether the vitriolic acid will produce a precipitate;

if

If it does, the water contains terra ponderosa aerata, (or barytic aerocrate). After this, let some vitriolic acid be mixed with distilled boiling water; when, if a precipitate is formed, it is owing to the muriatic salt of the terra ponderosa contained in the water.

(*e*) Alum.

The most simple means of discovering whether water of any kind contains alum, are, to boil the water in a very clean copper vessel, when, if it contains alum, it will exhibit a blue colour. When the quantity of alum in the water is small, the blue colour is not sensible; but it may be rendered very manifest by the addition of a little caustic volatile alkali. This method of discovering alum in water, by means of copper, is founded on the property of this salt, in virtue of which it always exists with an excess of acid: it is this surplus of acid which acts upon the copper. A more certain method is to pour a solution of fixed alkali into the water, and to see whether the precipitate made by this means dissolves in water, impregnated with fixed air; if it does, it is not earth of alum.

D. Metallic salts.

Nothing is better adapted to the purpose of discovering the presence of metallic salts in waters, than the Prussian alkali purified by acids. If a solution of this alkali be poured into this water, after it has been exposed for some time to the air filtered, it makes a precipitate, which will be blue, if the water contains iron; brown, if it contains copper; and white, if it contains zinc. In case the Prussian alkali is not at hand, a solution of fixed alkali may be used in its stead. This with iron, forms a yellow; with copper, a green; and with zinc, a white precipitate. This last precipitate becomes yellow, when exposed to the action of the fire.

(*a*) Aerated iron.

Water, which contains aerocrate of iron, has its colour changed by an infusion of galls, but not by the Prussian alkali; however after such water has been exposed for some time to the air, the iron is precipitated out of it, and it ceases to be affected by this infusion. If a water, exclusively of this aerated iron, contains an alkaline salt, the colour struck by the infusion of galls is rather red than violet.

(*b*) Phlogisticated iron dissolved in mineral acids.

Iron in this state has the property of changing the colour of the infusion of galls to purple, and to black, and of the solution of Prussian alkali to blue. If the colour of this mixture be not distinct, the water must be exposed for some time to the air, and afterwards filtered: some Prussian alkali purified by acids must then be added to it; in consequence of which the mixture will become blue.

(*c*) Dephlogisticated iron dissolved in acids.

Iron which has lost a certain portion only of its phlogiston, will dissolve in vitriolic acid: but if it has lost too great a quantity of it, it is not soluble in this, although it be in the muriatic acid. If the iron contained in the water be in this latter state, the water will be made blue by the phlogisticated alkali, but will not be affected by an infusion of galls. In a water of this kind, let a piece of polished steel be steeped, and the water evaporated till it is reduced to one half. Now, acids having more affinity with iron, while it retains its phlogiston, than after it has been deprived of it, the iron in the former state will expel that in the latter, and at the same time impart phlogiston to it; and thereby enable it to strike a black or deep purple colour with an infusion of galls.

For the purpose of learning in what acid the iron is dissolved, a smaller quantity of a solution of terra ponderosa in the nitrous acid must be addedto it; when, if it throws down a yellow precipitate, and the water loses its inky taste, the iron is dissolved in the acid of vitriol; but if, on the contrary, it does not lose this stiptic taste, it is combined with marine acid. In this experiment, likewise, the water is to be filtered as soon as the whole has settled; when the greatest part of it will remain upon the filtering paper; if now a little marine acid be poured upon it, its olive colour will be changed to a fine blue.

(*d*) Iron in two different states in the same water.

A water of this kind deposites ochre, a short time after it is exposed to the air, and yields at the spring with Prussian blue, a green or olive-coloured precipitate.

E. Cupreous salts.

Water which contains these salts, acquires a distinct blue colour from a few drops of volatile alkali, and yields a brown precipitate by the addition of a little phlogisticated alkali.

F. Zincine

F. Zincine ſalts.

Water that contains theſe ſalts affords with Pruſſian blue a white precipitate, which becomes yellow in the fire, and turns white again as ſoon as it is cold.

G. Arſenic.

If this ſubſtance be contained in the water, it will be diſcovered by pouring a ſolution of volatile liver of ſulphur into the water, from which it will be precipitated of a yellow colour. A ſolution of gold may likewiſe be uſed for this purpoſe; as gold in ſolution being added to a water that contains arſenic, will fall down after ſome time in its metallic form. From a water of this kind the ſolution of martial vitriol throws down a black precipitate. The water may likewiſe be boiled down, and the reſiduum be thrown upon live coals; if it ſmells of garlick, the water contains arſenic.

H. Combination of acids with mangaueſe.

If, on a little of a ſolution of vegetable alkali being poured into water, a white precipitate is formed, and if the precipitate becomes black in the fire, and is ſoluble neither in the nitrous nor in the vitriolic acid, the water contains manganeſe.

I. Liver of ſulphur.

Nitrous acid deſtroys the odour of the waters, which contain theſe ſubſtances, and ſeparates the ſulphur. On the other hand, the vitriolic and common marine acids augment the ſmell, while they ſeparate the ſulphur. But if it be requiſite to render the ſulphur viſible, the experiment muſt be made with a conſiderable quantity of water, and the whole ſuffered to ſtand undiſturbed for ſome time. The ſolutions of lead, ſilver, and quickſilver in nitrous acid, and the ſolution of corroſive ſublimate, yield with a water of this kind a brown or elſe a black precipitate; which, when dried, will burn, on a red-hot ſhovel, with a blue flame, and a ſulphureous ſmell.

K. Hepatic air.

The pure vitriolic and the phlogiſticated marine acids neither augment nor diminiſh the odour of the water that contains this air; they likewiſe neither render it turbid, nor do they precipitate the ſulphur; this laſt is effected by the dephlogiſticated nitrous and marine acids, though in a very ſmall quantity only. At the ſame time too they deprive the water of its offenſive odour. The ſolutions of quickſilver, lead, and ſilver, do not yield any precipitate, except

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there is a confiderable quantity of this air employed; and what is more extraordinary, this precipitate does not burn with a flame. The folution of corrofive fublimate, and the nitrous folution of quickfilver made with heat, give with this kind of water a white precipitate. The calx of filver turns black in it, and deprives it of its offenfive odour; it lofes this fmell likewife in a copper veffel, after remaining in it a minute or two *.

L. Fixed air.

Waters which contain fixed air, change the colour of tincture of litmus to red; but this colour muft be carefully diftinguifhed from the reddifh hue exhibited by this tincture, when diluted with a great quantity of water, from which it is very different. According to Profeffor *Bergman*'s method, lime-water may likewife be ufed, a practice which however ftands in need of fome improvement. When a water contains a certain but fmall quantity of fixed air, it does not change the colour of the infufion of litmus; and in this cafe the quantity muft be afcertained by diftilling the water in a pneumatic apparatus. The tafte of the water indicates the prefence of this fubftance, only when the water contains a certain

* In order to obtain a water faturated with fulphureous gas, Dr. *Hahneman* expofes to a white heat, for a few minutes only, a pounded mixture of equal parts of fulphur and unflaked or frefh-flaked lime; and throwing half an ounce of this with five drachms of purified tartar into a bottle containing two pounds of pure luke-warm water, ftops it quickly with a cork, and after fhaking it for ten minutes, and allowing the groffer particles to fettle, pours off the milky liquor into another bottle, and mixes it by agitation with three or four tea-cups of thick cream, or half an ounce or two ounces of gum arabic, or half an ounce of gum tragacanth bruifed. Calcareous hepar requires 1920 parts of cold, and 840 of warm-water: Calcareous tartar 800 of cold, and 500 of warm for their folution.

For a warm bath he takes fourteen ounces of calcareous hepar and one pound of cream of tartar pounded, and ftirs them up in the water of the bathing-tub; or in 300 lb. of water made warm to 100 deg. he agitates three quarters of a pound of hepar, made with pot-afh, and then ftirs up with it very brifkly a quarter of a pound of ftrong oil of vitriol.—Or he takes four parts of fcales of iron fufed with three of fulphur, till it ceafes to yield a blue flame; puts half a pound of this mixed with five pounds of water, into a bottle holding eight or ten pounds; on this he then pours a quarter of a pound of oil of vitriol, inftantly ftopping it with a bladder tied over and pricked with a needle; finks it to the bottom of a high bathing tub, filled with warm water, and mixes the air as it comes out by agitation, with the water. Vid. Chem. Annal. II. Stuck 1788. Alfo *Hahneman*, uebern die Arfenikvergifung. Leipfick, 1786.

quantity

quantity of it; for it is by no means to be inferred, when the water does not taſte ſour, that it contains no fixed air; as the contrary circumſtance ſometimes takes place. A water of this kind generates bubbles at the ſpring, which burſt at its ſurface with ſome noiſe.

## SECT II. Of the ANALYSIS of MINERAL WATERS, properly ſo called.

THE Analyſis ſhows, in the firſt place, how much of each of theſe ſubſtances is contained in the water; and it is performed by evaporating the water, by which means one ſubſtance is obtained after another, when each of them is weighed ſeparate.

Some mineral waters contain volatile particles, which make their eſcape during the evaporation of the water; others contain ſuch ſubſtances, as are liable to be decompoſed by evaporation, or may more or leſs prevent the developement of the other parts.

Laſtly, all of them contain fixed ſubſtances, that remain behind in a dry and concrete ſtate, after the water is evaporated.

A. Separation of the volatile ſubſtances.

(*a*) In water which contains hepatic air, theſe ſubſtances occur.

If nitrous acid be poured on a portion of this kind of water, the quantity of ſulphur precipitated by it, gives the quantity of the hepatic air, contained in the water; each cubic inch of the latter containing a quarter of a grain of ſulphur. Another part of the water is to be evaporated, according to the method deſcribed farther on.

(*b*) Water ſaturated with fixed air.

Part of ſuch water is to be evaporated in the method deſcribed a little farther on. From another portion of it, according to Profeſſor *Bergman*, the air is to be expelled, and afterwards mixed with lime-water, for the purpoſe of aſcertaining the quantity of it. If *Bergman*'s preſcription be followed literally, the fixed air will be loaded with vapours of the water, which will paſs with it through the mercury, be con-

denſed

denſed on its ſurface, and afterwards abſorb part of the air. Excluſively of this, there is another inconvenience, viz. that the fixed air which occupies the ſpace left void in the retort cannot paſs through the mercury; and conſequently its quantity cannot be determined. It is better therefore to paſs the air immediately through lime-water; when one part precipitates along with the calcareous earth which it meets with in its paſſage, as does likewiſe the remainder, if the apparatus be ſhaken a little. This earth muſt be carefully ſeparated by filtration. Now as the quantity of fixed air contained in calcareous earth, and its ſpecific gravity, is very well known, it is eaſy to make an accurate eſtimate of the quantity of fixed air that is contained in the water; for inſtance, if half a drachm of calcareous earth be obtained, the water contains $18\frac{3}{4}$ grains of fixed air, or $32\frac{89413}{1000000}$ cubic inches; allowing with M. *Kirwan* a cubic inch of fixed air to weigh $\frac{57}{100}$ of a grain.

In default of a pneumatic apparatus, provided it be certain that the water does not contain any fixed alkali, it needs only to be mixed with four times its quantity of lime-water, and then filtered. The quantity of the calcareous earth thus obtained determines that of the fixed air preſent in the water.

If the water contains alkali, the experiment muſt be made twice, viz. firſt at the ſpring, and afterwards when the water has been boiled; the weight of the ſecond ſediment is then to be ſubſtracted from that of the firſt, viz. of the aerated earth, and it will appear what allowance is to be made for the weight of the fixed air.

It is true, the earths diſſolved in the fixed air, and the muriatic earth diſſolved in vitriolic acid, are precipitated at the ſame time with the lime in the lime-water; but a farther proſecution of the analyſis will point out the quantity of this latter precipitate, by which means the error may be eaſily corrected.

B. Analyſis of the volatile alkaline Subſtances.

If a ſubſtance of this kind be ſuſpected in the water, let part of it, after having been weighed, be put in a retort, and about $\frac{1}{3}$ of it drawn off by diſtillation; a quantity of marine acid is then to be poured on the diſtilled portion, till the ſaturation is complete: the ſal ammoniac thus obtained is then to be dried and weighed; the quantity of acid in the ſal ammoniac being known, it is eaſy to eſtimate that of the volatile alkali in the water. *Wenzel's* eſtimate of the volatile alkali contained in ſal ammoniac, ſeems to be more exact than that of *Bergman*. If theſe waters contain particles that may be either eaſily decompoſed, or

alter

alter the product of the analyſis, they muſt be treated in the following method.

C. Separation of the Subſtances which are decompoſed during the evaporation of the Water, and which prevent the ſeparation of the other Ingredients.

Theſe ſubſtances are, liver of ſulphur, and metallic ſalts. The acid of ſulphur which was diſengaged during the evaporation, combines with the alkaline ſubſtances that may happen to be contained in the water, and changes their nature. In metallic ſalts, the metal loſes its phlogiſton, ſeparates from its acid, and enters into new combinations with the other ingredients of the water. Hence the liver of ſulphur, as well as the metallic ſalt, muſt be decompoſed, and an eſtimate made of the quantity, in which they are preſent in the water, previous to undertaking the evaporation.

(*a*) Water, that contains liver of Sulphur.

For the purpoſe of analyſing a water that contains liver of ſulphur, a quantity of nitrous acid muſt be poured into it ſufficient to precipitate all the ſulphur. The precipitate is then to be ſeparated, and weighed.

(*b*) Water that contains metallic Salts.

Pour into this water a ſolution of Pruſſian alkali previouſly purified by means of nitrous acid; as ſoon as the precipitation ceaſes, the water muſt be filtered, and the precipitate drained, and weighed. The weight of the precipitate will give the weight of the metallic ſalt. The different colours which the phlogiſticated alkali exhibits with the different metals, has been mentioned above. Before this article is diſmiſſed, it may be neceſſary to obſerve, that the various ſalts are formed in theſe proceſſes by the union of the re-agents with the ſubſtances that previouſly exiſted in the water. The ſalts ſo formed, are cubic and calcareous nitre, vitriolated tartar, and digeſtive ſalt. However theſe cannot occaſion the leaſt difficulty to the chemiſt, ſuppoſing, for inſtance, after making the analyſis of a ſulphureous water, he finds a certain quantity of nitre; for, this nitre being formed with the mineral alkali previouſly contained in the water, he has only to look into the annexed Table, and he will find how much mineral alkali this quantity of nitre contains, whence he may eaſily deduce the quantity of the mineral alkali preſent in the water.

D. Sepa-

D. Separation of the fixed and immutable Subſtances.

The Separation of the volatile bodies, and of ſuch as may prevent the ſeparation of the fixed and immutable ſubſtances, having been effected; let a certain quantity of the water be weighed, and, after being evaporated to dryneſs, weighed again. The evaporation is beſt performed in veſſels of glaſs, or china. It is true, that a weak heat only can be uſed with ſuch veſſels, and that conſequently the evaporation goes on but very ſlowly in them. But this inconvenience is balanced by the certainty that the operator has, that the water has no other matter united with it.

In whatever manner the evaporation is performed, the reſiduum conſiſts of ſalts which are ſoluble in the pureſt ſpirit of wine, of ſuch as are ſoluble in cold water, and of ſuch ſubſtances as are not to be diſſolved by either of theſe menſtrua. Conſequently the firſt thing to be done is to pour a quantity of rectified ſpirit of wine on the reſiduum, and let them digeſt together for the ſpace of a few hours, in a gentle heat. (This ſpirit diſſolves all ſalts except the vitriolated ſalts, the ſalts perfectly neutralized with mineral acids, and mild or aerated alkalies). The liquor is then to be decanted into another veſſel, in order that its contents may be farther analyzed, and in the mean time the analyſis of the remainder is to be continued. With this view a quantity of cold water is to be poured upon the reſiduum, which muſt ſtand in a gentle heat for the ſpace of ſix or eight hours, and be ſhaken now and then. The water is then to be decanted off into another glaſs, and ſome freſh water added to the remainder; after ſtanding one or two hours longer, the water in both glaſſes is to be mixed and filtered, and ſet apart for the purpoſe of examining its contents. Theſe conſiſt of ſalts perfectly neutralized, and vitriolic ſalts, excluſively of ſelenite. That part of the reſiduum which is inſoluble in water and ſpirit of wine, conſiſts of different earths, of the ſelenite and of the iron that has been diſſolved in the fixed air of the water. The Bodies which have been diſſolved in both liquids, are now to be ſeparated from each other, as muſt the ſubſtances that compoſe the undiſſolved reſiduum.

(A) Separation of the Subſtances diſſolved in the Spirit of Wine.

Theſe may be either ſedative ſalt, common ſalt, nitrous acid combined with an earth, arſenic, or extractive matter.

There are three methods of ſeparating theſe ſubſtances.

*Firſt*

*First Method.*

(*a*) For sedative Salt. The vinous spirit is to be mixed with twice its quantity of distilled water, and part of this mixture evaporated; if this be suffered to crystallize, sedative salt is obtained, of all the salts that are soluble in spirit of wine the only one that is crystallizable.

(*b*) Salts with a calcareous basis.

If the re-agents indicate a calcareous salt in the water, the calcareous earth is to be separated by the acid of sugar saturated with alkali. The quantity of the precipitate thus obtained, gives the quantity of the calcareous salt contained in the water. The salt acquired by crystallization, whether it be nitre or digestive salt, shews with what acids the calcareous earth is combined. In order to separate this salt more accurately, the liquor may be evaporated to dryness, and the soluble part of the residuum extracted with spirit of wine; consequently the digestive salt and cubic nitre, being insoluble in the spirit, are left behind. After these are separated, the spirit must be diluted with distilled water, and the undissolved substances separated by the method mentioned below.

(*c*) Salts, the basis of which is Heavy Earth or Barytes.

If in consequence of the analysis made with the re-agents, the presence of a salt of this kind is suspected in the water, let a solution of Glauber's salt, or vitriolated tartar be poured into the water: and the quantity of re-generated heavy spar will, with the assistance of the annexed Table, shew the quantity of the salt contained in the water. After this either the digestive salt, or the nitre, whichsoever it be, that is formed by this decomposition, must be separated.

(*d*) Salts, the basis of which is Murioecic Earth.

If the water contains a portion of these salts, there must be added a quantity of fixed alkali to the liquor that is left after the preceding experiment. The consequence of this will be, that the murioecic earth, (or magnesia,) will be precipitated; and from the crystals, either of digestive salt or nitre, which may be separated either by crystallization or precipitation with spirit of wine, it will appear with what acid the earth was united. If the weight of these last salts, or that of the precipitated earth be known, the quantity of Epsom salt in the water may be easily estimated.

(*e*) Arsenic.

If there be any reason to suspect this substance in the water; to the above-mentioned liquor, before it is suffered to crystallize, a small quantity of volatile

liver of ſulphur may be added; thearſenic will ſpeedily unite with the ſulphur: and afterwards the digeſtive ſalt, or the nitre, whichſoever of theſe is preſent, may be ſeparated from the liver.

(*f*) Extractive Matter.

Laſt of all, the Extractive Matter muſt be ſeparated from the ſpirit of wine. With this view the liquor that remains after theſe various proceſſes muſt be evaporated to dryneſs. Some particles of it however adhere to the cryſtallized ſalts, as do likewiſe ſome ſaline particles to the attractive matter.

*Second Method.*

This method is founded on the obſervation that, except arſenic, and ſedative ſalt, all others which ſpirit of wine is capable of holding in ſolution, contain an earth. The vinous ſpirit charged with theſe ſubſtances, being mixed with a ſufficient quantity of water, and the arſenic and ſedative ſalt being thus ſeparated from it, let a ſolution of ſilver in nitrous acid be poured into it; the precipitate hereby obtained, indicates the quantity of marine acid that was preſent in the water combined with the earth. The remainder of the liquid is then to be precipitated with fixed alkali: a more preciſe analyſis of the earth obtained, will ſhew the nature and quantity of the ſalts of which it made a component part.

If beſides theſe, there are in the water other ſalts, the earth of which is combined with nitrous acid, in this caſe the quantity of the earth obtained will not correſpond with that of the marine acid, as indicated by the ſolution of ſilver. But as all ſalts in which the marine acid is combined with an earth contain nearly the ſame quantity of earth, nothing more is neceſſary to be done, than to ſubſtract from the earth obtained by the foregoing proceſs, the quantity ſufficient to ſaturate the marine acid in a liquid ſtate, and the remainder will give the weight of the earth diſſolved in the nitrous acid.

For the purpoſe of aſcertaining the nature and quantity of the earth obtained, let the precipitate made by the fixed alkali be diſſolved in nitrous acid, to which muſt be added drop by drop, a ſmall quantity of a ſolution of acid of ſugar ſaturated with fixed alkali. In conſequence of this the calcareous earth will be precipitated, and combined with the acid of ſugar, and the weight of the precipitate will point out the quantity of the calcareous earth contained in the liquor. Now, if after this the liquor be ſeparated from this precipitate by decantation, and a ſolution of alkali ſaturated with fixed air, be poured into it,

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the muriatic and aluminous earth will be likewife precipitated. Laftly, let there be poured upon this mixture a quantity of diftilled water, faturated with fixed air: the former of thefe earths will be diffolved, while the latter will be left undiffolved.

### *Third Method.*

The arfenic and fedative falt being feparated, let the remaining liquor be diluted with three times its quantity of water, and the earth precipitated from it with fixed alkali; the liquor being decanted off from the earthy precipitate, which muft be analyzed in the method abovementioned, let there be poured into the former a fmall quantity of folution of filver. The weight of the precipitate here produced fhews the quantity of marine acid that was combined with the earth.

(B) Separation of the fubftances that are foluble in diftilled Water.

Thefe may be fixed alkali faturated with fixed air, all the perfect neutral falts, alum, Epfom falt, and other falts.

(*a*) Fixed Alkali.

It is hardly poffible to afcertain the quantity of mineral alkali that is contained in any water by the cryftallization of this falt; for fome part of it always mixes with the other falts, and it can never be obtained in a pure ftate. Let therefore any quantity of Epfom falt, but rather more than is fufficient, be taken to faturate the alkali in the water. The water will become turbid, and in the fpace of five or fix hours let fall a quantity of muriatic earth. Now as the quantity of mineral alkali requifite for decompofing the murioecic falt, as well as the quantity of magnefia yielded by it, may be found in the annexed Tables, the quantity of earth obtained, will of courfe give that of the decompofed Epfom falt, and this the quantity of mineral alkali contained in the water. In like manner may be difcovered the quantity of the Glauber's falt that arifes from this decompofition. But the redundant quantity alfo of Glauber's falt that may exift in the water, as well as that of the Epfom falt employed in this procefs, muft be taken into confideration. Thefe are the only means on which any dependence can be placed in analyzing alkaline waters.

(*b*) Alum and Epfom Salt.

If thefe falts are found together in water, either with or without any other falt, the beft mode of afcertaining the quantity of them, is to decompofe them: thus let a folution of fixed alkali be added drop by drop to the water, till it ceafes

ceaſes to render the water turbid. The precipitate being waſhed, dried and weighed, a quantity of diſtilled water ſaturated with fixed air muſt be poured upon it, which will diſſolve the murioecic, but not the aluminous earth; the weight of the latter ſubſtracted from the whole of the precipitate, will give the weight of both earths; and the quantity of the alum and the Epſom ſalt may be eaſily determined from the Tables. The analyſis is to be continued, and the vitriolated tartar formed by the decompoſition, muſt be ſeparated. This may be eaſily done by cryſtallization.

If the Epſom ſalt be mixed with Glauber's ſalt, it is almoſt impoſſible to ſeparate them by cryſtallization, as both of them cryſtallize at the ſame time. Here, as before, recourſe muſt be had to the decompoſition of them. The portion of Glauber's ſalt contained in the water may be determined by the weight of the precipitated earth; the ſame holds good with reſpect to alum, when mixed with other ſalts.

(*c*) Glauber's Salt, common Salt, and Nitre.

1. A ſolution of terra ponderoſa in nitrous acid, is to be poured into water, that has ſtood ſome time on the reſiduum of the evaporated water, and the precipitate dried and weighed. By this means the quantity of Glauber's ſalt contained in the water will be aſcertained.

2. Into this water that has been ſeparated from the abovementioned precipitate by filtration, let a quantity of ſolution of ſilver in nitrous acid be poured; this will cauſe a precipitate which muſt be ſeparated from the ſupernatant liquid, and, when dry, weighed, for the purpoſe of diſcovering the quantity of common ſalt contained in the water.

3. If the weight of the Glauber's ſalt and common ſalt, taken together, be ſtill not equal to that part of the reſiduum that has been diſſolved in cold diſtilled water, this circumſtance gives room to ſuſpect that there is nitre in it, the quantity of which is diſcoverable by the difference of the others.

As in theſe experiments the heavy earth and ſilver are diſſolved in the ſame nitrous acid, and the one is uſed after the other; there is no reaſon to fear the effects either of a combination, or of a decompoſition.

(C) Separation of the ſubſtances contained in that part of the reſiduum of the Water, which is not ſoluble either in ſpirit of Wine, or in cold Water: viz. Selenite, Iron, Siliceous, Aluminous, Murioecic, Calcareous and heavy Earth.

I. Selenite. The reſiduum, after being weighed, is to be boiled with 500 times its weight of diſtilled water; the Selenite will be diſſolved, and will paſs through

through the filter with the water, while the iron and the earth will remain behind. The remainder muſt now be dried upon the filter, and weighed; if the weight be ſubſtracted from its former weight before it was boiled, it will give that of the ſelenite.

In order to ſeparate the ſelenite, marine acid may likewiſe be poured on the reſiduum; the acid will diſſolve the iron and the earths, and the ſelenite will remain behind, together with a little ſiliceous matter. For the purpoſe of aſcertaining the quantity of the latter, nothing more is neceſſary than to waſh the reſiduum with diſtilled water; what remains after this is ſiliceous earth, the quantity of which is eaſily determined.

II. Siliceous earth. The Selenite being ſeparated in the form of theſe methods; upon what remains on the filter, after it has been dried and weighed, pour a quantity of marine acid, when it will all diſſolve except the ſiliceous earth, and the deficiency in the weight will determine the quantity of this earth.

There is no reaſon to fear but that the iron in the ſtate in which it occurs here, is poſſeſſed of phlogiſton enough to be diſſolved in the marine acid; for this acid diſſolves iron, even when the latter has loſt almoſt all its phlogiſton; but whichſoever method is followed, a ſolution of iron and earths in the marine acid is obtained.

III. Iron. Into this ſolution let there be poured a little Pruſſian alkali purified by means of marine acid, the iron will be precipitated in the form of Pruſſian blue: how much iron this contains may be found in the annexed Tables. The Pruſſian alkali muſt be previouſly purified by acids, in order to prevent the precipitation of the earthy ſalts, and to make the precipitate charge itſelf more perfectly with the colouring matter. In Profeſſor *Bergman's* method, the ſiliceous earth combines with the alkali, and in this caſe it is very difficult to aſcertain the quantity of it.

IV. Calcareous earth. After the ſeparation of the iron by means of the Pruſſian alkali, the liquor is ſtill charged with different kinds of earths. In order to ſeparate the calcareous earth from this liquor, a ſolution of acid of ſugar ſaturated with alkali muſt be added drop by drop, when the calcareous earth will be precipitated in the form of (calx ſaccharata, or) calcareous oxalidicrate.

V. Murioecic and Aluminous Earths.

In order to obtain theſe earths from the liquor ſtanding upon the calcareous oxalidicrate, a ſolution of fixed alkali is to be added to it, till the precipitation ceaſes;

ceafes; the precipitate, which confifts either of earth of alum, or murioecic earth, or both together, is then to be wafhed, dried, weighed, and put into a large bottle that is perfectly air-tight, and the bottle is to be filled with diftilled water perfectly faturated with fixed air; this will diffolve the murioecic earth, and leave the aluminous earth behind.

We fhall finifh this fketch of the analyfis of mineral waters with fome Tables to which we have frequently referred, and which will be ufeful in making an eftimate of the fubftances that are obtained by the decompofition. The valuations of the contents are given from Profeffor *Bergman*, Mr. *Kirwan* and M. *Wenzel*; though I am apt to imagine that we fhall make nearer approaches to the truth, by taking the average of thefe three eftimates.

*Note, to have been inferted at the bottom of Page* 640.

In this as well as moft other explofive mixtures, the pure air is feparated from the bafe of the acid, and uniting with the bafe of the fubftance that affords the phlogifton, expells and decompofes this latter principle. This is the cafe in all rapid combuftions from mere mixture; in which, when the deflagrating fubftances contain the nitrous acid, the explofion proceeds from the fudden difengagement of the mephitis, that is now left behind uncombined with any other fubftance. To this caufe may be attributed not only the phenomenon mentioned above in the Text, but alfo the inflammation of oils as well as of charcoal in the nitrous acid, the explofion of gunpowder and pulvis fulminans, that of phofphorus as mentioned at page 619, in the fame acid, and that which enfues from the commixture of this acid with fpirit of wine in the procefs for making æther. But the explofions that take place in *Bayen's* mercurial precipitates, when triturated with fulphur, (which all contain air) as well as that which is afferted by *Scheele*, in his Treatife on Air and Fire, to have been produced by the union of zinc with arfenic, together with many others recorded by chemical writers, are merely to be attributed to the air contained in them being difengaged too quickly; i, e, to a larger quantity being difengaged at once than can be attracted and fixed in the fame fpace of time by the fubftance that affords the phlogifton.

In fact, the heat excited in the folutions of metals in acids, appear to proceed entirely from the union formed by the pure air with the bafe of the metal in the previous calcination, in confequence of the rapidity with which this latter element paffes from a fluid to a folid ftate. And, in general, the combination of any fubftance with air, produces heat; not, as M. *Lavoifier* and Dr. *Crawford* affirm, becaufe it is air only that contains heat, or that this element contains more heat than any other fubftance; but becaufe all bodies give out heat from their interftices in proportion to the rapidity with which they are reduced from a fluid to a folid ftate. [E]

A TABLE shewing the MUTUAL PROPORTION of the CONSTITUENT PRINCIPLES in different SALTS.

100 PARTS of

| | | ALKALI. | ACID. | WATER, |
|---|---|---|---|---|
| Vitriolated Tartar, according to | *Bergman* - - - | 52 | 40 | 8 |
| ——— ——— ——— | *Kirwan* - - - | $64\frac{61}{100}$ | $30\frac{31}{100}$ | $5\frac{18}{100}$ |
| ——— ——— ——— | *Wenzel* - - - | $55\frac{3}{12}$ | $44\frac{1}{3}$ | $\frac{5}{12}$ |
| Glauber's Salt, according to - | *Bergman* - - - | 15 | 27 | 58 |
| ——— ——— ——— | *Kirwan* - - - | $21\frac{87}{100}$ | $13\frac{19}{100}$ | $64\frac{94}{100}$ |
| ——— ——— ——— | *Wenzel* - - - | $19\frac{1}{2}$ | $24\frac{1}{3}$ | $55\frac{5}{6}$ |
| Nitre, according to - - - | *Bergman* - - - | 49 | 33 | 18 |
| ——— ——— ——— | *Kirwan* - - - | $63\frac{97}{100}$ | $29\frac{89}{100}$ | $6\frac{14}{100}$ |
| ——— ——— ——— | *Wenzel* - - - | 48 | $51\frac{2}{3}$ | $\frac{5}{6}$ |
| Digestive Salt, according to - | *Bergman* - - - | 61 | 31 | 8 |
| ——— ——— ——— | *Kirwan* - - - | $63\frac{97}{100}$ | $29\frac{68}{100}$ | $6\frac{85}{100}$ |
| ——— ——— ——— | *Wenzel* - - - | $62\frac{1}{2}$ | $33\frac{7}{8}$ | $3\frac{3}{8}$ |
| Common Salt, according to | *Bergman* - - - | 42 | 52 | 6 |
| ——— ——— ——— | *Kirwan* - - - | 50 | $33\frac{3}{100}$ | $16\frac{7}{100}$ |
| Cubic Nitre, according to - - | *Kirwan* - - - | $50\frac{9}{1000}$ | $28\frac{8}{100}$ | $21\frac{11}{100}$ |
| Tartarus Tartarisatus, according to | *Bergman* - - - | $33\frac{1}{2}$ | $62\frac{1}{3}$ | $4\frac{1}{6}$ |
| Depurated Tartar, according to | *Bergman* - - - | 23 | Sat. acid 43 | Acid 34 |
| | | Earth. | Acid. | Water. |
| Selenite, according to - | *Bergman* - - - | 32 | 46 | 22 |
| ——— ——— ——— | *Kirwan* - - - | 32-34 | 29-34 | $38\frac{56}{100}$ |
| ——— ——— ——— | *Wenzel* - - - | 32 | 48 | 20 |
| Epsom Salt, according to - | *Bergman* - - - | 19 | 33 | 48 |
| ——— ——— ——— | *Kirwan* - - - | 19 | $23\frac{75}{100}$ | $57\frac{25}{100}$ |
| ——— ——— ——— | *Wenzel* - - - | $21\frac{1}{12}$ | $37\frac{1}{2}$ | $40\frac{5}{12}$ |
| Alum, according to - - | *Bergman* - - - | 18 | 38 | 44 |
| ——— ——— ——— | *Kirwan* - - - | 18 | $23\frac{94}{100}$ | $58\frac{6}{1000}$ |
| ——— ——— ——— | *Wenzel* - - - | $29\frac{2}{3}$ | $23\frac{2}{3}$ | $46\frac{2}{3}$ |
| Calcareous Nitre, according to | *Bergman* - - - | 32 | 43 | 25? |
| ——— ——— ——— | *Kirwan* - - - | 32 | $33\frac{28}{100}$ | $34\frac{72}{100}$ |
| ——— ——— ——— | *Wenzel* - - - | $25\frac{1}{2}$ | 50 | 24? |
| Murioecic, or Magnesian Nitre, - according to | *Bergman* - - - | 27 | 43 | 30? |
| ——— ——— ——— | *Kirwan* - - - | 27 | $35\frac{64}{100}$ | $33\frac{36}{100}$ |
| ——— ——— ——— | *Wenzel* - - - | 20 | 50 | 30 |
| Calcareous Muria, according to | *Bergman* - - - | 44 | 31 | 25? |
| ——— ——— ——— | *Kirwan* - - - | 38 | $42\frac{56}{100}$ | $19\frac{44}{100}$ |
| ——— ——— ——— | *Wenzel* - - - | 37 | 38 | 25? |
| Murioecic Muria, according to | *Bergman* - - - | 41 | 34 | 25? |
| ——— ——— ——— | *Wenzel* - - - | $41\frac{1}{9}$ | $33\frac{1}{3}$ | 25? |
| Calcareous Saccharocrate, according to | *Bergman* - - - | 46 | 48 | 6 |
| Murioecic Saccharocrate, - | *Bergman* - - - | 35 | 65 Acid | and Water |
| Alumitic Saccharocrate ——— | *Bergman* - - - | 44 | 56 | - - |
| | | Metal. | | |
| Vitriol of Copper, according to | *Bergman* - - - | 26 | 46 | 28 |
| ——— ——— ——— | *Kirwan* - - - | 27 | 30 | 43 |
| ——— ——— ——— | *Wenzel* - - - | $26\frac{5}{12}$ | $32\frac{117}{234}$ | 41 |
| Vitriol of Iron, according to - | *Bergman* - - - | 23 | 39 | 38? |
| ——— ——— ——— | *Kirwan* - - - | 25 | 20 | 55 |
| ——— ——— ——— | *Wenzel* - - - | 21 | 28 | 51? |
| Vitriol of Zinc, according to - | *Bergman* - - - | 20 | 40 | 40 |
| ——— ——— ——— | *Kirwan* - - - | 20 | 22 | 58 |
| ——— ——— ——— | *Wenzel* - - - | 29 | 33 | 38 |
| Luna Cornea, according to - | *Wenzel* - - - | $75\frac{45}{192}$ | $22\frac{86}{192}$ | 0 |
| ——— ——— ——— | *Kirwan* - - - | 75 | 18 | 1. |

* I allow 51 Parts of Water in 100 Parts of Vitrol of Iron, and I have marked it with a Note of Interrogation; because M. *Wenzel* has not determined the Quantity of Water of Crystallization, having contented himself with indicating the Proportion of the Acid to the Iron.

TABLE.

## A TABLE shewing the Quantitity of the WATER of CRYSTALLIZATION contained in different SALTS.

| 100 PARTS of | *Bergman.* | *Kirwan.* | *Wenzel.* | |
|---|---|---|---|---|
| Vitriolated Tartar | 8 | 1 | $\frac{5}{12}$ | |
| Nitre | 18 | 3 | $\frac{5}{6}$ | |
| Glauber's Salt | 58 | $42\frac{66}{100}$ | $55\frac{5}{6}$ | |
| Cubic Nitre | | $2\frac{71}{100}$ | $3\frac{3}{4}$ | |
| Sea Salt | 6 | $3\frac{7}{100}$ | $2\frac{1}{12}$ | |
| Digestive Salt | 8 | 1 | $3\frac{1}{3}$ | |
| Tartarus Tartarisatus | | | $4\frac{1}{6}$ | |
| Salt of Seignette | | | 25 | |
| Terra foliata Tartari | | | $45\frac{5}{12}$ | |
| Borax | | | 40 | |
| Mineral Alkàli | | | $62\frac{1}{2}$ | |
| Selenite | 22 | 24 | 20 | |
| Calcareous Saccharocrate | 6 | | | |
| Cathartic, or Epsom Salt | 48 | 48 | $40\frac{5}{12}$ | |
| Calcareous Tartar | | | $45\frac{5}{12}$ | |
| Alum | 44 | 44 | $46\frac{2}{3}$ | |
| Vitriol of Iron | 38 | | 51 | *Struve* |
| —— of Copper | 28 | | 41 | *Struve* |
| —— of Zinc | 40 | | $38\frac{3}{4}$ | *Struve* |

## A TABLE shewing the Quantity of FIXED AIR which enters the ALKALINE AEROCRATES, or Aerated Substances.

| 100 PARTS of | | contain: Fixed Air. | Pure Alkali. | Water. | Earth. |
|---|---|---|---|---|---|
| Vegetable Alkali perfectly saturated with fixed Air, | *Bergman* | 20 | 48 | 32 | 0 |
| Fixed Nitre, melted | *Wenzel* | $27\frac{1}{2}$ | $69\frac{1}{2}$ | 0 | 3 |
| Alkali of Tartar | *Wenzel* | 30 | | | |
| Natrous Aerocrate, or Mineral Alkali, according to | *Bergman* | 16 | 20 | 64 | |
| —— —— —— | *Wenzel* | 15 | $22\frac{3}{8}$ | $62\frac{1}{2}$ | $\frac{5}{24}$ |
| Concrete Volatile Alkali, according to | *Bergman* | 45 | 43 | 12 | |
| —— —— —— | *Wenzel* | $53\frac{3}{4}$ | $33\frac{1}{2}$ | $12\frac{15}{24}$ | |
| | | | Pure Earth. | | |
| Terra Ponderosa, or Barytic aerocrate, according to | *Bergman* | 7 | 65 | 8 | |
| Calcareous Aerocrate, according to | *Bergman* | 34 | 55 | 11 | |
| —— —— —— | *Wenzel* | $43\frac{1}{3}$ | $52\frac{1}{6}$ | 5 | |
| Murioecic Aerocrate, or Magnesia, according to | *Bergman* | 30 | 40 | 30 | |
| —— —— —— | *Wenzel* | $32\frac{1}{2}$ | $41\frac{2}{3}$ | $25\frac{5}{6}$ | |
| Alumite, or Earth of Alum, according to | *Bergman* | 3 | 97 | | |

TABLE

## A TABLE shewing the Quantity of ALKALINE SUBSTANCES requisite for the Saturation of various ACIDS.

| | | According to *Bergman.* | According to *Kirwan.* | According to *Wenzel.* |
|---|---|---|---|---|
| 100 PARTS of Vitriolic Acid require, of | Pure Vegetable Alkali - - - - - - | $127\frac{1}{2}$ | 214 | $102\frac{1}{2}$ |
| | Pure Mineral Alkali - - - - - - - | $56\frac{1}{2}$ | 167 | 79 |
| | Pure Volatile Alkali - - - - - - - | 42 | | 70 |

| | | *Bergman.* | *Kirwan.* | *Wenzel.* |
|---|---|---|---|---|
| 100 PARTS of Fixed Air require, of | Pure Alumite, or Earth of Alum - - | 30 | | |
| | Pure Murioecite, or Magnesia - - - - | 150 | | $128\frac{1}{4}$ |
| | Pure Lime, or Calcareous Earth - - | 162 | | 121 |
| | Pure Barytes, or Heavy Earth - - | 926 | | |

| | | According to *Bergman.* |
|---|---|---|
| 100 PARTS of Acid of Sugar require, of | Mild Vegetable Alkali, or Spodic Aerocrate | 200 |
| | Mild Mineral Alkali, or Natrous Aerocrate | 200 |
| | Caustic Volatile Alkali obtained from Sal Ammoniac by distilling it with four Parts of Quick-lime and three of Water | 600 |
| | Calcareous Spar - - - - - - - - - | 122 |

## A TABLE shewing the Quantity of ACID requisite for the Saturation of ALKALINE SUBSTANCES.

| | | According to *Bergman.* | According to *Kirwan.* | According to *Wenzel.* |
|---|---|---|---|---|
| 100 PARTS of pure Vegetable Alkali require, of | Vitriolic Acid - - - - - - - - - | $78\frac{1}{2}$ | 47 | $82\frac{1}{2}$ |
| | Nitrous Acid - - - - - - - - - | 64 | $46\frac{1}{2}$ | 108 |
| | Marine Acid - - - - - - - - - - | $51\frac{1}{2}$ | $46\frac{1}{2}$ | $54\frac{1}{2}$ |
| | Fixed Air - - - - - - - - - - | 42 | | $42\frac{6}{7}$ |
| 100 PARTS of pure Mineral Alkali require, of | Vitriolic Acid - - - - - - - - - | 177 | 59 | 126 |
| | Nitrous Acid - - - - - - - - - | $135\frac{1}{2}$ | 57 | $167\frac{1}{2}$ |
| | Marine Acid - - - - - - - - - - | 125 | 67 | $83\frac{3}{4}$ |
| | Fixed Air - - - - - - - - - - | 80 | | 53 |

## A TABLE ſhewing the Quantity of METAL contained in different METALLIC PRECIPITATES.

According to *Bergmann*.

| 100 PARTS of the following METALS diſſolved in their appropriated ACIDS, | yielded PRECIPITATES with the following SUBSTANCES. | Parts. |
|---|---|---|
| Silver | Marine Acid | 133 |
| | Vitriolic Acid | 134 |
| Mercury | Vitriolic Acid | 119 |
| Lead | Vitriolic Acid | 143 |
| Iron | Phlogiſticated Alkali | 590 |
| | Mild Alkali | 225 |
| Gold | Cauſtic Alkali | 110 |
| | Mild Alkali | 106 |

EXPLANA-

# EXPLANATION

## OF THE

# PLATES.

## PLATE I.

FIG. I. A REVERBERATING FURNACE.

*a*, The aſh-hole door.
*b*, The fire-place door.
*c*, *c*, *c*, *c*, Regiſters.
*d*, The dome or reverberatory.
*e*, The conical funnel.
*f*, The retort in the furnace.
*g*, The receiver.
*h*, *h*, Iron bars to ſuſtain the retort.

FIG. 2. This figure repreſents a furnace called an ATHANOR. This figure and the following deſcription are copied from *Cramer*'s *Art of Aſſaying*. "This furnace is uſed for the diſtillation of acid ſpirits, for calcinations, cementations, &c. As theſe operations require a long and conſtant fire, an athanor is uſeful, becauſe it can contain as much fuel as will keep up the fire for many hours together, and admits of a different, an accurate, and moſt conſtant regimen of the fire.

"Let then, 1ſt, a ſmall ſquare hollow tower *(a a a a)* be conſtructed of ſuch *ſtones*, [or of bricks made of *Stourbridge clay*, or *Windſor loam*,] as may reſiſt the fire; let the ſides of it be ſix inches thick, and forming a ſquare cavity within, of ten inches on each

ſide (*b b b b*). The height of it is determined according as it is to keep up the fire long, without any addition of freſh fuel: five or ſix feet are moſt commonly ſufficient. 2. At the bottom of this tower make an opening (*c*), ſix inches broad, and as many inches high; hang to it an iron door, being on every ſide one inch broader than the opening, and ſuch as may ſhut it very cloſe: for which purpoſe the external edge of this opening muſt be excavated all round in ſuch a manner, that it may form a groove one inch broad, into which the edges of the door may be received. 3. At the diſtance of ten inches from the bottom of the tower, put a grate (*d*), made of priſmatical, quadrangular iron-bars, one inch thick, and three quarters of an inch diſtant from each other: let alſo each of theſe iron bars be ſo ſituated with regard of the tower, that the two oppoſite acute edges of each may look perpendicularly, one downward, the other upwards, that, by this means, the aſhes may eaſily fall into the aſh-hole. 4. Make above this grate an opening circular at top (*e*) ſix inches high, ſeven inches broad, that may, as well as the aſh-hole (No. 2), be opened and ſhut with an iron door. 5. Adapt to the top of the tower an iron cover (*f*), exceeding the aperture of the tower all around two inches, and having a handle, wherewith it may be eaſily taken away, and put on again. Thus you are to make the furnace called in Latin *furnus primarius*. 6. Then cut out in any ſide of the tower, for inſtance, in the left, an oblong ſquare aperture, going up obliquely towards the outſide (*g g*), four inches and a half high, ten inches broad, having its inward inferior edge one inch and a half, or two inches above the grate (*d*); that by the intervening of this hole, the cavity of this tower may communicate with another immediately to be deſcribed. 7. Nearly over againſt the ſame ſide of the tower, make a cavity with ſtones, whoſe inferior part muſt be a hollow priſm (*h*, *h*, *h*, *h*,) ſix inches high, twelve inches broad, ending at top in a ſemi-cylindrical arch (*i*, *i*,) deſcribed by a *radius* of ſix inches; that by this means, the height of the whole cavity may be twelve inches in the middle. Let this interior cavity be totally open, though, when requiſite, it is to be ſhut very cloſe with an iron plate (*k*, *k*,) whoſe inward ſurface is to be conſtructed in the ſame manner as is preſcribed for the ſliding door of the melting furnace, (FIG. 4.) and then luted two inches thick within. Moreover, let there be in the middle of this plate, a round hole, four or five inches in diameter, and let the circumference of this hole have an iron cylindrical border made to it, and prominent within; that by means of it, the lining of lute within may be ſupported, and kept from falling down eaſily. Let a notch one inch broad, and two inches deep, be made in the outward circuit of the aperture of this cavity, to receive the extremity of the plate that ſhuts the aperture. The hole of this plate either is ſhut with a ſtopple, or ſerves to paſs the neck of the retort through. This plate likewiſe is faſtened with two bolts (*n*, *n*, ), to be put horizontally with iron hooks (*o*, *o*, *o*, *o*,) driven into the wall near the edge of the aperture, ſo that one bolt may faſten the upper part of the plate, and the other the lower. 8. It is moreover proper, that the ſquare aperture (*g*, *g*,) through which the fire enters from the tower into the cavity hitherto deſcribed (No. 7.), may be ſhut and opened at pleaſure

with

with an iron ſlider: for if this is not done, an exceſſive fire, employed ſometimes by an unexperienced hand, cannot be ſo eaſily checked. For this purpoſe, let a ſlit half an inch broad, and eleven inches long, be left in the wall that conſtitutes the upper part of the cavity (No. 7.), and is contiguous to the tower; ſo that it may exceed the length of the ſquare aperture, (*g*, *g*,) a ſmall matter on every ſide, and reach before and behind into the ſmall groove, going down along the perpendicular ſides of the ſaid aperture, (*g*, *g*,) and retain the iron ſlider to be put into it to keep it ſteady. However, let this iron ſlider be ſix lines thick, eleven inches broad, and five inches high; and let a couple of ſmall iron chains (*p*, *p*,) be faſtened on each ſide of its upper edge, wherewith the ſlider may be lifted up and let down again. Therefore let a couple of ſtrong iron nails be drove into the contiguous wall of the tower, perpendicularly over thoſe places in which the ſaid ſmall chains are faſtened to the iron ſlider, that any of the links of the chains may be ſuſpended on them at pleaſure. Moreover, let the upper edge of the ſlit above deſcribed be entirely ſhut up with ſtones and cement, leaving only two ſmall holes through which the ſmall chains may be paſſed. On the left of this cavity (No. 7.), and at the diſtance of eight inches from the bottom of it, let a ſquare (*q*, *q*, *q*, *q*,) chimney or funnel be erected with *bricks*, three inches and a half in the clear, four foot high, and a ſmall matter convergent upwards, ſo that the diameter of it at top may be three inches. This funnel muſt be contrived to ſhut cloſely with an iron ſlider, having a handle to it (*r*, *r*,), which ſlider muſt move freely between a double iron ſquare frame faſtened in the walls of the funnel, at ſuch a height from the hearth as ſhall ſeem convenient to any artificer. 10. Below this chimney let a ſquare aperture be made, like the foregoing (No. 6. *g*, *g*,), leading obliquely up to the bottom of another cylindrical cavity (*u*, *u*, *u*, *u*,) which is eight inches deep, deſcribed by a *radius* of ſix inches, open at top, and there converging inwardly into a border one inch thick, and ſix lines broad, deſigned to ſupport an iron pot. Likewiſe, cut in the interior wall of this cavity, and at the upper part of its mouth, a ſegment two inches and a half deep, five inches broad, and ſtooping forward (*v*, *v*,) to receive the neck of the retort. 11. To this cavity (No. 10.) belongs an iron pot (*w*, *w*,) eleven inches broad, and about nine inches deep, which muſt be encompaſſed with an iron ring (*x*, *x*,) one inch broad, and faſtened at the diſtance of one inch and a half from the upper end of the pot. Let a ſegment (*y*) be likewiſe cut off the upper edge of this pot, which ſegment muſt be four inches and a half deep, and five inches broad: the iron ring juſt deſcribed muſt be bent all round the edges of this ſegment. 12. Over-againſt the aperture (*t*, *t*,) which communicates from the firſt cavity (No, 7.) into the ſecond (No. 10.), let another ſuch aperture (*z*) be made, two inches diſtant from the bottom of the ſecond cavity (No. 10.) perfectly like the foregoing (*g*, *g*, *t*, *t*,) and communicating obliquely upwards with a third cavity (1, 1, 1, 1,), like equal to the ſecond cylindrical cavity (*u*, *u*, *u*, *u*,); that the fire may paſs from the latter into the former. 13. In the hinder part of the wall which makes the aperture juſt mentioned (*z*), let a chimney like

like the foregoing (*q, q, q, q,*), and of the same height (2, 2, 2, 2,), be erected, which may be shut with a slider like that (3). 14. Finally, on the left side of the third cavity let an aperture be made in the same manner (4), and like the foregoing ones (*g g t t z*); more remote however from the bottom of the cavity, without a passage at the other extremity, and communicating only with a cavity of the third chimney (5, 5, 5,), which must be erected in the same manner as the two foregoing ones (*q, q, q, q,* 2, 2, 2, 2,). Thus you will have a furnace very proper for a great many operations.

"We are now to speak of the use of the *Athanor* just described; and chiefly to mention, to what operations each of its parts serve in particular, and then how the fire may and must be governed in it. 1. You must put at the upper arched door (*e*) of the tower a semi-cylindrical muffle twelve inches long, which must be introduced through the door: which for this reason must be of the same height and breadth as that door, three quarters of an inch thick, and open behind, being shut there by the hinder part of the athanor, as far as which it must reach. For this purpose, a *tile* must be set upon the grate (*d*) to support the muffle. Let also this muffle have small pieces cut out near its basis, as common assay-muffles. You may put under this muffle your cement pots, or such bodies as must be calcined with a long and violent fire; which can be done without a muffle, though not so neatly. 2. In the first chamber (*h, h, h, h, i, i,*) you may make the most violent distillations with an open fire: for retorts or large vessels are introduced into it, after you have taken away the door (*k, k, k,*), and are put either upon the hearth itself of this chamber, or upon a particular support of stone. But you must place these vessels in such a manner, that their necks may easily pass through the hole of the door, when put on again: for which purpose, they chuse a support sometimes higher, sometimes lower, according to the different heights of the vessels. When afterwards the door is put on again, and fastened with both its bolts (*n, n,*), you must close with lute all the chinks which lie open about the neck of the vessel, and between the edges of the door and the entrance of the chamber. Then you apply to the neck of the vessel a cylindrical segment, ten or more inches long: by means of which the heat and the boiling vapors coming forth are gradually diminished; lest the recipient, which is always chosen a glass vessel, should split. The recipient, which must be united with the other orifice of the said segment, is supported either by the pavement, or by a certain kind of trivet, the construction of which is such, that it may be set lower or higher by means of three screws. 3. In this same chamber, instead of distillations, you may also make cementations, calcination, &c. in which case the round hole of the iron plate may be shut, and again opened with a stopple, that one may view the inside. 4. The second and third cavities (*u, u, u, u,* 1, 1, 1, 1,) serve chiefly for such operations as are made in baths [or beds] of *sand, ashes*, or *filings*. For instance, you put into each of these cavities a pot, (*v, v,*), and you stop with thin *lute* or with *sand*, which must previously be moistened, the slip between the iron ring (*x, x,*) and the border of the cavity, upon

which

which this ring refts. 5. Befides, you may alfo make in thefe two cavities, diftillations by a reverberating fire, as well as in the firft: only the fire is lefs violent in thefe, though fufficient to extract aqua fortis. You then take out the iron pot (*v*, *v*,) and inverting it, you put it upon the mouth of the chamber; fo that the brim of the pot, being the depth of one inch and a half above the iron ring (*x*, *x*,) wherewith this pot is furrounded, may be received within the mouth of the cavity, and fo that the fegment cut in the pot (*y*) may, together with the fegment cut out from the fide of the cavity (*v*, *v*,) form a hole to let the neck of the veffel through. 6. All the *apparatus* being thus ready, you firft introduce through the top of the tower (*b*, *b*, *b*, *b*,) a few burning coals; and put upon them fome of the unkindled fuel of the fire; that the cavity of the tower may, according as it is thought neceffary, be filled either entirely or only in part. Then with all fpeed you put upon it the iron cover (*f*), and ftrew the border of this on the outfide with *fand* or *afhes*, which you prefs gently with your hands: for if you fhould neglect this point, all the fuel contained in the tower would be kindled, and may endanger fetting the houfe on fire.

We fhall here annex a few general rules concerning the regimen of the fire in this furnace: for it is hardly neceffary to explain all particulars, fince practice will readily hint them to fuch as fhall be ever fo little acquainted with Chemiftry. The fire may be made very ftrong in the firft chamber, (*h*, *h*, *h*, *h*, *i*, *i*,) when the door of the afh-hole (*c*), and the funnel (*q*, *q*, *q*, *q*,) of the chamber is quite open, and when the iron flider fufpended with chains (6. *p*, *p*,) does not hinder the fire from paffing freely from the tower into this cavity. But the clofer the funnel is fhut, together with the door of the afh-hole, the more the violence of the heat diminifhes: and this will be foon effected, if the iron flider fufpended with chains is let down in part: for the fuel contained in the tower burns at leaft as high as the fpace between the lower edge of the iron flider and the grate (*d*). Obferve befides, in thofe operations wherein the round hole of the door is ftopt with a plug, that when the ftrongeft fire is required, this hole muft not be kept long open; becaufe the air rufhing violently through it, foon cools the bodies put into the cavity. The operations abovementioned may be performed in the fecond and third chamber, in, and at the fame time, and with the fame fire, as they are in the firft chamber; for the fire penetrates from the firft cavity into the fecond, and increafes when the funnel (2, 2, 2, 2,) erected on it is opened: but before you do this, the funnel of the firft cavity muft be fhut as much as that of the fecond is opened. By the fame means, you may hinder the fire, which ferves for the operations made in the two firft cavities, from going out through the funnels, and you force it out, on the contrary, through the third cavity and through its funnel (5, 5, 5,); that it may alfo act upon the bodies placed in that cavity. For the more the funnel erected upon the third cavity is open, the more one, or even both funnels of the other two cavities muft be clofed: thence it is plain, that you cannot kindle the ftrongeft fire in the third cavity, unlefs there be one equally ftrong in the other two; and that, on the contrary, the heat

heat in the third cavity may be rendered lefs, by clofing its funnel; though it be violent in the others. The fame is true of the fecond cavity, with regard to the firft. Finally, you cannot make the ftrongeft fire under the muffle placed within the upper door (*e*) of the tower, unlefs yon have an equal fire in the firft cavity, which fire may confequently be increafed, by fhutting the door quite againft the muffle (*e*), and diminifhed by opening it; there being meanwhile an equal heat in the firft chamber, and in the following ones. The reft will eafily be learned by practice."

FIG. 3. *An* ASSAY *or* CUPELLING FURNACE. This figure and the following defcription of this furnace are copied from *Cramer's Art of Affaying*. *See Dr. Mortimer's Englifh Edition, p.* 75.

"The affaying Furnace is made in the following manner: 1. Make with iron plates a hollow quadrangular prifm, eleven inches broad, and nine inches high (*a a*, *b b*,) ending at top in a hollow quadrangular pyramid (*b b*, *c c*,) feven inches high, terminating in an aperture at top feven inches fquare. This prifm muft be clofed at bottom with another iron plate, which ferves as a bafis or bottom to it (*a a*). 2. Near the bottom make a door (*e*) three inches high, and five inches broad, that leads to the afh-hole. 3. Above this door, and at the height of fix inches from the bafis, make another door (*f*), of the figure of a fegment of a circle, four inches broad at its bafis, and three inches and a half high in the middle. 4. Then faften three iron plates on the forepart of this furnace; let the firft of them (*g g*), eleven inches long, and half an inch high, be faftened, fo that its lower edge fhall reft againft the bottom of the furnace, with three or four rivets, and in fuch a manner, that there may be between the upper edge of the faid plate and the fide of the furnace a groove fo wide, as that the fliders of the lower door (*k k*) may be put into it, and freely move backwards and forwards therein: thefe muft be made of a thicker iron plate. The fecond iron plate (*h h*), eleven inches long, three inches high, and perfectly parallel to the foregoing plate, muft be faftened in the fpace between the two doors, in fuch manner, that both the upper and the lower edge of it may form a hollow groove with the fide of the furnace. One of thefe grooves, which is turned downwards, ferves to receive the upper edges of the fliders that fhut the lower door (No. 2). The other, that turns upwards, is to receive the inferior edges of the fliders of the fmall door above (No. 3). The third plate (*i i*), which is like the firft, muft be rivetted clofe above the upper door, in fuch manner, that it may form a groove turning downwards, and contiguous to the upper edge of the upper door (No. 3). 5. In order to fhut both doors (No. 2 and 3), you muft adapt to each of them two fliders made of iron plates, that may move within the abovementioned grooves (*k k*, *l l*); but the two fliders belonging to the upper door (No. 3.) muft have each a hole near the top; that is, one a fmall hole, one fifth part of an inch broad, and one inch and a half long (*m*); and the other a femi-circular aperture, one inch high and two inches



broad,

broad (*n*). Let, besides, each slider have a handle, that they may be laid hold of when they are to be moved. 6. Moreover, let five round holes, one inch broad, be bored in the furnace, two of which must be made in the fore part of the furnace (*o o*), two others in the back part, all at the height of five inches from the bottom, but three inches and a half distant from each side of the furnace; and, finally, a fifth hole (*p*), at the height of one inch above the upper edge of the upper door (*f*). 7. In short, let the inside of the furnace be armed with iron hooks, jetting out half an inch, and about three inches from each other, to fasten the lute with which the furnace is to be covered over within. 8. Let then an iron, moveable, hollow, quadrangular pyramid (*q*), three inches high, be adapted to the upper aperture (*d*) of the furnace, at the basis, seven inches broad, ending upwards in a hollow tube (*r*), three inches inches in diameter, two inches high, almost cylindrical, though somewhat convergent at top. This prominent tube serves to support a funnel or flue, which is almost cylindrical, hollow, made of iron plates, and two foot high, and which, when a very strong fire is required, is put perpendicular upon the shorter tube, in such manner, that it enters close into it, one inch and a half, or two inches deep, and may again be taken off at pleasure, when there is no need of so strong a fire. But this pyramidal cover (*q*) must besides have two handles (*s s*) adapted to it, that it may be laid hold of, and thus be taken away or put on again: and that this being put on the aperture (*d*) of the furnace, may not be easily thrown down, let an iron plate be rivetted to the right and left upper edge of the furnace (*c c*), and be turned down towards the inside, so as to make a furrow, open before and behind, into which the lateral edges of the cover may enter and be fastened, and at pleasure be moved backwards and forwards, whenever it must be put on, or moved. 9. Let a square ledge, made of a thick iron plate, be fastened at top of the upper edge of the lower door (*e*); this is designed to support the grate and the lute: but it must be made of two pieces, that it may be easily introduced into the cavity of the furnace. Thus you will have an assay-oven, which must afterwards be covered over on the inside with lute. This you are to do as follows:

" That the fire may be better confined, and that the iron may not be destroyed by growing red-hot, the whole inside of the furnace must be covered over with lute, one finger, or one finger and a half thick. The lute fit for this is made of a mass of clay mixed with sand, and moistened with three or four times as much of ox-blood diluted with water *. But before you cover the inside of your furnace with this lute, you must first put within the furnace

* The best lute, and easiest to be had at London, is a sort of clay called Windsor loam, which must be mixt pretty stiff, and pressed into the inside of the furnace, first wetted with water; and when the clay begins to dry, it must be beat down close to the sides with a wooden mallet; then the unevenness and cracks filled up with fresh clay somewhat moister, so as to be made smooth and even with a trowel, and then left to dry gently; and if any cracks happen, they must again be filled up. *Note of Dr. Mortimer.*

ſmall iron bars, equal in length to the diameter of the oven, quadrangular, priſmatical, half an inch thick, having their extremities ſupported by a ſquare iron ledge, and three-fourths of an inch diſtant from each other; and you muſt faſten them ſo, that their flat ſides may be oblique with regard to the tranſverſe ſection of the furnace, and that the two oppoſite angles may look one upwards and the other downwards; the bars muſt not be laid flat, but edgeways, by which ſituation you hinder the aſhes of the fuel of the fire from being detained too long between the interſtices of the ſaid iron bars, and from making an obſtruction that would oppoſe the free draught of the air. The furnace being then covered over with lute, and dried up by a gentle heat, is at laſt fit for docimaſtical operations, and eſpecially for ſuch as muſt be performed in the aſſay-oven.

If then an operation is to be made in the furnace hitherto deſcribed, you muſt let through the four lower holes above deſcribed, of the furnace (*o o*) placed before and behind, and directly oppoſite to each other, two iron bars, one inch thick, and long enough, that their extremities on every ſide, may jut out of the holes a ſmall matter. Theſe ſerve to ſupport the muffle and its bottom (*See* Plate L. Fig. 9.). You then introduce the muffle through the upper aperture of the furnace (*d*), and place it upon the above deſcribed iron bars, in ſuch manner, that the open foreſide of it be contiguous to the inward border of the upper door (*f*). The fuel of the fire is introduced through the top of the furnace (*d*); the cover of which, on this account, muſt be moveable, and not very heavy (*q*). The beſt fuel for the fire is charcoal made of the hardeſt wood, eſpecially of beech, broken into ſmall pieces of the bigneſs of an inch, wherewith the muffle muſt be covered over ſome inches high. We then reject larger bits of coals, becauſe they cannot fall through the narrow interſtices, between the ſides of the muffle and thoſe of the furnace, and cannot of courſe ſufficiently ſurround the circumference of the muffle. Whence it happens, that there are on every ſide places void of fuel, and the fire is either not ſtrong enough, or unequal. But if, on the contrary, you uſe coals too ſmall, then a great part fall immediately through the interſtices of the grate, into

Stourbridge clay, tobacco-pipe clay, or any other pure clay that is not fuſible by fire, may be uſed for this purpoſe. But as freſh clay ſhrinks and cracks very much in drying, it ought to be mixed with an equal quantity or more of coarſe white ſand, or of burnt clay groſsly powdered. Thus one part of Stourbridge clay, one part of coarſe white ſand, and one part of Stourbridge bricks groſsly powdered, being well mixed together, make a good lute for lining the inner ſurfaces of furnaces. To prevent the iron plates of the furnaces more effectually from calcination, their inner ſurfaces ought to be covered with a coating of charcoal-powder, formed into a maſs or paſte, with as much freſh clay and water as are ſufficient for that purpoſe; and when this coating is dry, the abovementioned lute may be applied. During the drying, the lute ought to be daily beat with a mallet, that the ſpaces left by the ſhrinking of the clay may be cloſed, and the lute be rendered more compact. *Note of Mr. Keir.*

the aſh-hole; and the tendereſt particles of them turn too ſoon into *aſhes*, and by increaſing the heap of aſhes, obſtruct the free draught of the air, which is here greatly requiſite.

" A perfect management of the fire is moſt commonly neceſſary in the performing of operations in this furnace; therefore the reader muſt give attention to what follows: If the door of the aſh-hole (*e*) is quite open; and the ſliders of the upper door (*f*) drawn towards each other, ſo as to touch one another in the middle of the door; and if, beſides, the cover (*q*), and the funnel adapted to its tube (*r*), is upon the top (*q*) of the furnace, the fire will be then in the higheſt degree poſſible; though, in the mean time, it is hardly ever neceſſary to put the funnel on, except in a very cold ſeaſon: but if, after having diſpoſed the furnace in the manner juſt deſcribed, you put red burning coals into the open upper door (*f*) of it, the fire is ſtill more increaſed thereby: however, this artifice is never, or very ſeldom, neceſſary. When you ſhut the upper door with only that ſlider that has a narrow oblong hole in it (*m*), then the heat becomes a little leſs; but it diminiſhes ſtill more when you ſhut the door with the other ſlider that has in it the ſemi-circular hole (*n*), which is larger than that of the firſt ſlider: nay, the heat again is leſs when you take away the funnel put at top of the cover: finally, the door of the aſh-hole being either in part or totally ſhut, the heat is ſtill diminiſhed, becauſe the draught of the air, ſo neceſſary to excite the fire, is thereby hindered: but if, beſides all theſe, you likewiſe open the upper door quite, then the cold air, ruſhing into the muffle, cools the bodies put under it, that are to be changed, to a degree never required in any operation, and ſuch as will entirely hinder the boiling of lead. If, during the operation, the fire begins to decay, or to grow unequal, it is a ſign that there are places void of coals between the ſides of the furnace and thoſe of the muffle; therefore, in this caſe, you muſt ſtir your coals on every ſide with an iron rod, which is to be introduced through the upper hole (*p*) of the furnace, that they may fall together, and thus act in a proper manner and equally.

" However, you are to obſerve concerning the regimen of the fire juſt deſcribed, that though the *apparatus* is made with all the exactneſs mentioned, nevertheleſs the effect does not always anſwer it. The cauſe of which difference has moſt commonly its origin in the various diſpoſitions of the air; for as every fire is more excited by coals in proportion as the air, more condenſed, and more quickly agitated, ſtrikes them more violently (which the effect of bellows plainly ſhews); it thence appears, that in warm and wet weather, when the atmoſphere is light, the fire muſt be leſs efficacious in furnaces; that likewiſe when ſeveral furnaces ſituated near each other, are burning at the ſame time, the fire is in part ſuffocated; becauſe the ambient air is thereby rendered more rare and lighter. The ſame effect is produced by the ſun, eſpecially in ſummer-time, when it ſhines upon the place where the furnace is ſituated. The atmoſphere, on the contrary, being heavier in cold dry weather, excites a very great fire.

" The heat of the fire acts the ſtronger upon the bodies to be changed, as the muffle put in the furnace is leſs; as the ſaid muffle has more and larger ſegments cuts out of it; as the ſides

ſides of this muffle are thinner; in ſhort, as there are more veſſels placed in the hinder part of the muffle; and on the contrary. In this caſe, when many of the conditions requiſite for the exciting of fire are wanting, then indeed the artificer, with all his ſkill, will hardly be able to excite the fire to a ſufficient degree, in order to perform operations well, in common aſſay-ovens, even though he uſes bellows, and puts coals into the upper door of the furnace. For this reaſon I have put the grate almoſt three inches below the muffle, leſt the air, ruſhing through the aſh-hole, ſhould cool the bottom of the muffle, which happens in common aſſay-ovens; and again, that the ſmaller coals, almoſt already conſumed, and the aſhes, may more eaſily fall through the interſtices of the grate, and the larger coals ſtill fit to keep up the fire be retained. Finally, I have added the above-mentioned funnel, that the blowing of the fire being, by means of it, increaſed as much as poſſible, this might at laſt be carried to the requiſite degree; for the fire may always be diminiſhed, but not always, be increaſed at pleaſure, without the aſſiſtance of a proper *apparatus*."

FIG. 4, 5, 6, 7 *and* 8, repreſent a MELTING FURNACE. Theſe figures and the following deſcription of this furnace are copied from *Cramer*'s *Art of Aſſaying Metals*.

The melting furnace is made of iron-plates, the inner ſurfaces of which are covered with lute. The cavity of it may be formed according to an elliptical mould. 1ſt, Make an hollow ellipſis, the focus's 12 inches aſunder, and the ordinate 5 inches long; cut it off in both its focus's, that it may aſſume the figure (*Fig*. 4.). 2dly, Then make in this hollow body, and near its lower aperture, four holes, eight lines in diameter, and directly oppoſite (*c*, *c*,). 3dly, Then faſten two flat iron-rings (*d*), almoſt one inch and a half broad, at both the upper and lower inward edge of this oval cavity; and fill the inſide of it with ſmall iron-hooks, jutting out about ſix lines, and three or four inches diſtant from each other. Theſe, together with the rings juſt mentioned, ſerve to faſten the lute. Thus will the body of the furnace be made: only you muſt add at the outſide two iron handles (*e*, *e*,) to be rivetted on each ſide of it, that it may be taken hold of and moved. 4thly, Then make the cover of the furnace, which may be formed like the part cut off from the ellipſis (See *Fig*. 5,). Let this have an opening (*b*) made in it, four inches high, five inches broad at bottom, and four inches at the top; and adapt to this an iron door hung on hinges to ſhut it cloſe, and having at the inſide a border faſtened to it, anſwering exactly to the circumference of the door, and as prominent inwardly as the thickneſs of the lute to be applied to it requires: for the ſame purpoſe, let ſmall iron-hooks be faſtened to the inſide of the door, which is intercepted by the ſaid border. And leſt this cover ſhould be burnt within by the force of fire, you muſt cover the inſide of it over with the ſame lute mentioned before for the aſſay-oven: therefore it muſt be likewiſe furniſhed with a ring and iron hooks to faſten the lute; as was ſaid before, when we ſpoke of the body of this furnace. Beſides this, you muſt faſten two iron-handles (*Fig*. 5. *c*, *c*,) on the outſide of this cover. Then a round hole muſt be made on the top of it, being three inches in



diameter,

diameter, prolonged into a hollow tube (*d*) almoſt cylindrical, and a few inches high, upon which the iron funnel deſcribed may, in caſe of neceſſity, be put after the manner mentioned in the ſame place where we ſpoke of the aſſay-oven. 5thly, After this, the lining of both the body and cover of the furnace within is made in the ſame manner above-deſcribed. Moreover, you muſt make for this furnace two moveable bottoms, *viz.* one to receive the aſhes, and admit the air; the other to ſerve for reductions. The firſt is made with an iron-plate, formed into a hollow cylinder, open at top, and to be ſhut at bottom with an orbicular iron-plate, as with a baſis, five inches high, and of ſuch a diameter, as that it may receive the inferior orifice of the body of the furnace (*Fig.* 4.) the depth of half an inch (See *Fig.* 6.): therefore let an iron-ring (*c*), half an inch broad, be faſtened on the inſide of the ſaid bottom, and at the diſtance of half an inch from its upper border, to ſupport the body of the furnace put into it. Again, let this bottom have a ſquare door, four inches high, and as many inches broad, that may be ſhut cloſely with a door hung on hinges, that you may by means of it increaſe or diminiſh the draught of the air, and thus govern the fire at pleaſure. Then, on the left ſide of this door, and at about half the height of this bottom part, let a round hole (*d*) be made, one inch and a half in diameter, to admit the pipe of the bellows when need requires. Next to this, let another bottom part be made of the ſame matter and figure as the foregoing: let it be likewiſe of the ſame diameter, but two inches higher, ſo that it may be of the height of ſeven inches. Likewiſe let it have round it a like iron-ring below its upper border, to ſupport the body of the furnace to be received in it. But let a hole two or three inches broad, and one inch high (*Fig.* 7. *c.*), be cut out juſt below the ring in the ſide of this bottom part; then let another round hole be made in the left ſide of this firſt hole, fit to admit the pipe of the bellows (*d*). Further, let another round hole like the foregoing (*e*) be made on the right, and at the diſtance of one inch from the bottom: then let the whole inſide of this bottom part (the part above the ring excepted) be overlaid with lute, and a bed be made at the bottom, of a figure like that repreſented by the line (*f*, *g*, *h*,). The matter of which this is made is common lute pulverized, paſſed through a ſieve, and mixed with ſuch a quantity of duſt of charcoal, ſifted in the ſame manner, ſo that the mixture being moiſtened and preſſed down, may at leaſt be lightly coherent. Of this matter preſſed on the bottom of the bottom part a bed is made, like a ſegment of a ſphere, having in the middle a ſmall cavity ſomewhat lower, and made extremely ſmooth, after the manner mentioned before when we ſpoke of large aſh-veſſels or teſts.

This furnace is chiefly fit for fuſions, which may be made in it with and without veſſels. When you are to melt with a veſſel, put the body of the furnace (*Fig.* 4.) upon the firſt bottom (*Fig.* 6.), that has a door to it to open on hinges; introduce two iron bars through the holes of the furnace (*Fig.* 4. *c*, *c*,); put upon them the iron-grate, which you are to introduce through the upper mouth of the furnace: then put in the middle of this grate a *brick* or ſquare *tile*, very ſmooth every where, warmed, and perfectly dry: otherwiſe, the

veſſels

veſſels put upon it, eſpecially the large ones, are eaſily ſplit by the moiſt vapors coming out of it in the operations. Let the height and width of this *ſtone* be a ſmall matter broader and higher than the bottom of the crucible or pot to be ſet upon it; for if it were leſs high, the bottom of the veſſel could not be ſufficiently warmed; and if it were leſs broad, the veſſel might eaſily fall from it: then put upon this *tile* the veſſel containing the matter to be melted, and ſurround it immediately with coals on every ſide, which muſt be ranged according to the method preſcribed before, in our deſcription of the aſſay-furnace: then you govern the fire, by opening and ſhutting the door of the aſh-hole (*Fig.* 6. *b*): you excite it by putting the cover (*Fig.* 5.) upon the body of the furnace; and if, beſides, you put a funnel upon the cylindrical mouth (*d*) of this cover, the melting fire becomes ſtill more violent: but if you moreover introduce the bellows through the hole of the bottom part (*Fig.* 6. *d*); and the joint of the furnace with the bottom part, and the door of the aſh-hole, unleſs it can be ſhut very cloſe, being exactly ſtopt with thin lute [*or Windſor loam*], the fire thus excited by the blaſt of the belluws is carried to the higheſt degree, and far ſurpaſſes that which may be made in a Smith's forge. Another advantage of this method is, that the veſſels are not ſo eaſily broken, becauſe the blowing of the bellows cannot effect them immediately, and becauſe a fire perfectly equal is excited on every ſide. One may eaſily examine with this *apparatus*, how *ſtones* are effected by the violence of fire only. Now, if you have a mind to perform any operation without a veſſel, and with a naked fire; for inſtance, to melt and reduce the *calxes* or *ſcorias of copper*, *tin*, *lead*, and *iron*, or the ores of theſe metals; the body of the furnace muſt be put upon the other pedeſtal, having a bed in it (*Fig.* 7.). However, you muſt, before this, open with a knife the oblong hole (*c*), and the round one (*d*) of this bottom part, which are ſtopped with the lute ſticking to the inſide: then you apply at the round hole (*d*) on the left ſide of the bellows, in ſuch manner that the nozzle of it, being directed obliquely downwards, may blow ſtrongly againſt the bed (*f*, *g*, *h*,): by this means, all the aſhes that fall into the bed are blown away, and the ſtrength of the fire determined to ſuch a degree, that all the melted bodies that fall into the ſaid bed remain in their ſtate of fuſion; and were it otherwiſe, the melted bodies would immediately wax cold, and adhere in grains to the bed, whereas they ought to have melted into one *regulus*. The oblong hole in the fore-part of this bottom part (*c*) ſerves to diſcover, by means of a poker, whether the matter in the bed be melted or not: it ſerves likewiſe to take away through it whatever might ſtop the bellows, aand in ſome caſes to take away the *ſcoria*: then you put fi ſt coals into the furnace one ſpan high, and blow them well with the bellows, to make them burn, that the bed may be very hot, before the matter to be melted is put into it; for if this is not previouſly done, the melted maſs ſeldom runs into a *regulus*, but remains diſperſed among the *ſcorias*, which ſoon grow hard. The bed being well heated, and freſh coals added to the fire, put into it ſuch quantity of the matter to be melted as cannot hinder the fire being carried to the requiſite degree; which cannot be determined otherwiſe than by experience: again, put freſh coals, and upon them another

quantity

quantity of the matter to be melted; they may be, like *ſtrata*, one upon another: but if the maſs, once melted, could not long ſuſtain the ſtrength of the fire, or if you had a mind to melt a greater quantity of matter than what can be contained in the bed, you muſt open the round lower hole (*Fig.* 7. *e*), that you may make a channel paſſing from that hole through the lute, and reaching to the ſmall cavity at the bottom of the bed (*g*): to this hole, at the outſide, apply an earthen diſh like the bed within, or any other proper recipient, ſurrounded with burning coals, into which the matter melted running from the bed through the hole (*Fig.* 7. *e.*), may be collected as is repreſented by *Fig.* 8.

FIG. 9. 10. 11 and 12. Dr. *Black's* PORTABLE FURNACE, from the *Edinburgh New Diſpenſary*. To render our deſcription of this inſtrument as ſimple as poſſible, let the reader ſuppoſe that the body of the common ſtove is made of an oval form, and cloſed at each end by a thick iron plate. The upper plate or end of the furnace is perforated with two holes: one of theſe A, is pretty large, and is often the mouth of the furnace; the other hole B, is of an oval form, and is intended for ſcrewing down the vent upon.

The undermoſt plate or end of the furnace has only one circular hole, ſomewhat nearer to one end of the ellipſe than the other; hence a line paſſing through the center of both circular holes has a little obliquity forwards: this is ſhown in fig. 10. which is a ſection of the body of the furnace, and exhibits one half of the upper, and one half of the under nearly correſpending holes. The aſh-pit, fig. 9 and 10. C, is made of an elliptical form, like the furnace; but is ſomewhat wider, ſo that the bottom of the furnace goes within the brim; and a little below there is a border, D, fig. 10. that receives the bottom of the furnace. Except the holes of the damping plate, E, fig. 9 and 10. the parts are all cloſe by means of a quantity of ſoft lute, upon which the body of the furnace is preſſed down, whereby the joining is made quite tight: for it is to be obſerved, that in this furnace the body, aſh-pit, vent and grate, are all ſeparate pieces, as the furnace comes from the hands of the workman. The grate is made to apply to the outſide of the lower part, or circular hole: it conſiſts of a ring ſet upon its edge, and bars likewiſe ſet on their edges. From the outer part of the ring proceed four pieces of iron, by means of which it can be ſcrewed on: it is thus kept out of the cavity of the furnace, and preſerved from the extremity of the heat, whereby it laſts much longer. The ſides of the furnace are luted, to confine the heat, and to defend the iron from the action of it. The luting is ſo managed, that the inſide of the furnace forms in ſome meaſure the figure of an inverted truncated cone.

We have thus combined the two figures 9 and 10. in order to deſcribe as exactly as poſſible this furnace in its entire ſtate; but to prevent confuſion, it muſt be underſtood, that fig. 9 repreſents the body of the furnace with its bottom received within the aſh-pit. As in this figure, then, we could not exhibit the bottom of the furnace, we have in fig. 10. ſuppoſed the body of the furnace to be cut down through its middle; whereby one half of the undermoſt hole, with a proportional part of the grate, G, applied to it, is exhibited along

with,

with, and nearly oppoſed to, one half of the upper hole F; the ſame hole which in fig. 9. is repreſented in its entire ſtate by A. By fig. 10. then, the relation of the upper and under holes to one another is explained. It is alſo to be underſtood, that the aſh-pit of fig. 10. is not, like the body of the furnace, divided in its middle, but is the aſh-pit of fig. 9. only detached from the bottom of the furnace, in order to repreſent the border, D, on which the bottom of the furnace is received.

Now to adapt this furnace to the different operations in Chemiſtry, we may firſt obſerve, that for a melting furnace we need only provide a covering for the upper hole A, which in this caſe is made the door of the furnace. As this hole is immediately over the grate, it is very convenient for introducing and examining from time to time the ſubſtances that are to be acted upon. The cover for the door may be a flat and ſquare tile or brick. Dr. Black uſually employs a ſort of lid made of plate-iron with a rim that contains a quantity of luting. The degree of heat will be greater in proportion as we heighten the vent B, and to the number of holes we open in the damping-plate E: by this means the furnace may be employed in moſt operations in the way of aſſaying; and though it does not admit of the introduction of a muffle, yet if a ſmall piece of brick is placed upon its one end in the middle of the grate, and if large pieces of fuel are employed, ſo that the air may have free paſſage through it, metals may be aſſayed in this furnace without coming in contact with the fuel. It may therefore be employed in thoſe operations for which a muffle is uſed; and in this way lead and ſundry other metals may be brought to their proper calces.

When we wiſh to employ this furnace for thoſe diſtillations requiring an intenſe heat, the earthen retort is to be ſuſpended by means of an iron ring, having three branches ſtanding up from it, fig. 11. This ring hangs down from the hole A about one half foot; ſo that the bottom of the retort reſts upon the ring, and is immediately hung over the fuel. The opening between the mouth of the furnace A is filled up with broken crucibles or potſherds, and theſe are covered over with aſhes, which tranſmit the heat very ſlowly. This furnace, then, anſwers for diſtillations performed with the naked fire. Dr. Black has alſo had ſome of them provided with a hole in the ſide from which the neck of the retort iſſued; and in this way he has diſtilled the phoſphorus of urine, which requires a very ſtrong heat.

For diſtillations with retorts, performed in the ſand-bath, there is an iron pot (fig. 12.) fitted for the opening of the furnace A, and this is employed as a ſand-pot. In theſe diſtillations the vent B becomes the door of the furnace, and it is more eaſily kept tight than when on the ſide. When it thus ſerves for the door, it may be covered with a lid of charcoal and clay.

This furnace anſwers very well too for the common ſtill; part of which may be made to enter the opening A, and hang over the fire. In this caſe, likewiſe, the vent B is the door of the furnace, by which freſh fuel is to be added: but in ordinary diſtillations it is never neceſſary to add freſh fuel; and even in the diſtillation of mercury, phoſphorus of

urine,

urine, and indeed during any procefs whatever, the furnace generally contains fufficient to finifh the operation; fo effectually is the heat preferved from diffipation, and the confumption of the fuel is fo very flow.

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# PLATE II.

Fig. 4. A Glass Alembic.
A, The cucurbit.
B, The Head.
C, The Gutter within the beak.
D, The beak.

Fig. 1. A Long-Necked Glass Alembic.
A, The body of the matrafs.
B, The neck of the matrafs.
C, The Head of the alembic.

Fig. 5. A Glass Alembic *confifting of one piece.*
A, The cucurbit.
B, The head.
C, The aperture in the head.
D, Its ftopple.
E, The mouth of the cucurbit.

Fig. 21. A Pelican.
A, The cucurbit.
B, The head.
C, The aperture in the head with its ftopple.
D, The two curved fpouts.

 Fig. 7.

# EXPLANATION OF PLATE II.

FIG. 7. *A perpedicular ſection of a* CUPPEL *or* TEST. The curve line repreſents the cavity that contains the metal. The plan of any horizontal ſection of a cuppel is a circle.

FIG. 9. A MUFFLE.

FIG. 12. AN INGOT MOULD, into the cavities of which melted metals are poured.

FIG. 10. A RETORT. *See* alſo *Fig.* 8. A. where the beſt form of a retort is ſhewn.

A, Its belly or bowl.
B, Its neck.

FIG 13. Retorts of this form are called *Engliſh Retorts.*

FIG. 8. AN APPARATUS *for* DISTILLING, by which the vapors that uſually eſcape in the ordinary method of diſtillation, are condenſed by paſſing into water or ſome other fluid. This apparatus was invented and deſcribed by Mr. Peter Woulfe. *See the Phil. Tranſ. Vol.* LVII.

A, A retort. Inſtead of this retort, in the diſtillation of ſome ſubſtances, may be ſubſtituted an iron pot with a ſtone-ware head, the neck of which is to be inſerted into the receiver, as in the preſent Figure.

B, A receiver, with a neck, into which the neck of the retort is inſerted; and a ſpout at its bottom, through which the diſtilled liquor paſſes into the bottle C; and an opening in the ſide at D, into which one end of a tube bent at right angles is inſerted. The other end of this tube paſſes into a veſſel H, open at both ends, the lower opening of which is cloſed with a glaſs ſtopple. Through the upper mouth of the veſſel H, one end of another tube I, bent twice at right angles, paſſes, while the other end of this tube is inſerted into a bottle F, and immerſed in the water or other fluid contained in that bottle. The crooked tubes are fitted into the mouth of the veſſel H by means of a cork, in which are two ſemi-circular notches, through which the tubes paſs, and by lute.

The tube which paſſes into the bottle F is fitted into the mouth of this bottle by means of a cork, which is a ſemi-circular notch. This mouth of the bottle F is not cloſed with lute.

The vapor that is raiſed from the ſubſtance expoſed to heat in the retort paſſes into the receiver B, where part of it is condenſed, and flows into the bottle C, while the reſt of it paſſes through the tube at D, into the veſſel H. From this veſſel, the vapor that ſtill remains uncondenſed paſſes through the crooked tube I, into the water contained in the bottle F, by which it is all condenſed excepting ſome elaſtic air, which is extricated in almoſt all diſtillations. This elaſtic air ariſes through the water, and eſcapes at the ſemi-circular notch of the cork in the mouth of the veſſel, which is therefore not accurately cloſed by lute.

In

In moſt diſtillations a quantity of air is abſorbed at different times during the proceſs: and in this caſe the external air will preſs on the liquor in the bottle F, and force it through the tube I into the veſſel H, from which it may be taken by opening the ſtopple L.

The uſe of the veſſel H is to receive the liquor that may be thus raiſed from the bottle F, and to prevent it from paſſing into the receiver B, and from thence into the bottle C, where it might ſpoil the diſtilled liquor.

FIG. 11. *A Phial with a bent* TUBE *and* VALVE, lately invented by Dr. *Nooth*, for the purpoſe of preventing the liquid (whether mercury or water) into which the neck of the tube is immerſed, in the extrication of gaſes, &c. from entering into the tube and phial, and thus diſturbing the experiment. The principle on which it is conſtructed appears to be the converſe of the following.

FIG. 3. Dr. *Nooth's* APPARATUS *for impregnating Water with fixed Air*. It conſiſts of three veſſels, well fitted, by grinding, into each other, in the manner repreſented in the plate; and of a glaſs valve placed in the lower neck of the middle veſſel, ſo contrived, that it ſhall admit the gas, which is extricated from the effervеſcing materials contained in the middle veſſel, to paſs from this veſſel into that containing the water to be impregnated; but it ſhall prevent this water from falling into the lowermoſt veſſel. This valve conſiſts of three pieces, views of which are repreſented upon a larger ſcale by the figures *a*, *b* and *c*. The pieces *a* and *c* are cylinders fitted by grinding into the lower neck of the middle veſſel. The lower piece *c* is perforated along the axis of the cylinder. In the upper piece *a*, there are ſeveral very ſmall perforations parallel to its its axis. Between theſe two perforated cylinders is placed the piece *b*, which is a ſegment of a ſphere, and is moveable. The level ſurface of this ſegment reſts upon the upper, ſmooth, and level ſurface of the piece *c*, covering the perforation, and thereby preventing the water contained in the middle veſſel from falling into the lowermoſt.

When the apparatus is to be uſed, let the upper veſſel be diſengaged, and the middle one be filled with the water to be impregnated. Let as much water be poured into the lower veſſel as is ſufficient to cover the bottom of it. Some powdered chalk is to be thrown into this veſſel, and then, as much acid of vitriol, as may be thought ſufficient to ſaturate the chalk, is to be added. Theſe effervеſcing materials may be put into the lowermoſt veſſel, either through the mouth of this, after the middle veſſel has been diſengaged from it; or without diſengaging the middle veſſel, through the aperture at the bottom, which is afterwards to be accurately cloſed with a ground ſtopple. Laſtly, the upper veſſel is to be fitted to the lower one. When the gas ariſes from the effervеſcing materials contained in the lowermoſt veſſel, it paſſes through the perforation of the cylinder *c*; preſſes upon the level ſurface of the lenticular piece *b*; raiſes this piece a little upwards; eſcapes into the ſmall ſpace between the two cylinders *a* and *c*; and thence aſcends through the ſmall perforations of

of the cylinder *a*, and alſo through the water contained in the middle veſſel, in the upper part of which it remains collected. When the gas enters this veſſel, it forces ſome of the water, contained in this, to riſe into the upper veſſel, which is left open, or is only cloſed with a perforated ſtopper, that vent may be given to the contained air, when the water is thus forced into this upper veſſel.

The gas remaining in the upper part of the middle veſſel is gradually abſorbed by the water contained in this veſſel; and this abſorption may be promoted by frequent agitation, which brings new portions of the water into contact with the gas. The abſorption of gas is alſo promoted by the preſſure occaſioned by the column of water raiſed up into the uppermoſt veſſel. For preſſure facilitates the abſorption, as Mr. *Cavendiſh* has obſerved. The preſſure might be increaſed to any given degree, by a valve (ſimiliar to the ſafety-valve of a fire-engine) fitted into the mouth of the uppermoſt veſſel; or by a mercurial gage, as has been propoſed by Mr. *Warltire*, (*Prieſtley, Exper. and Obſerv. vol. III. Append.*) And thus a much ſtronger impregnation of water with gas may be effected, than is poſſible without artificial compreſſion. Cold alſo facilitates the abſorption, as appears from the experiments of Dr. *Hales*. For the more commodious agitation of the water, Mr. *Magellan* has added to the above deſcribed apparatus two more veſſels ſimilar to the upper and middle ones, by means of which the impregnation of water may be carried on at once in two ſets of veſſels, one of which ſets is to be agitated, while the other is receiving the gas from the efferveſcing mixture in the lower veſſel, and thus the water in each ſet of veſſels is alternately ſupplied with gas and agitated. By this method water may be impregnated with gas in a few minutes.

As the lowermoſt veſſel contains much air at the beginning of the operation, it is proper to let the efferveſcence proceed, during ſome minutes, before the ſeveral veſſels of the apparatus are joined together, that the greateſt part of the air may be expelled, before any gas is collected in the middle veſſel. When the water is ſufficiently impregnated, it may be occaſionally drawn off at the ſpout, by removing the ſtopper.

To the water thus impregnated with gas ingredients may be added to give it the peculiar qualities of the ſeveral mineral waters. Thus by adding a piece of iron to the impregnated water, the chalybeate property of *Pyrmont* water may be communicated.

This apparatus may likewiſe be uſed for digeſting various ſubſtances, ſuch as Camphor, Peruvian Bark, &c. in waters impregnated with fixed air, on which account it might perhaps be not improperly ſtiled the *Air-Digeſtor*.

FIG. 22. A TUB *with jars, &c.* for the purpoſe of transferring gaſes.

FIG. 14 and 15. The DOUBLE BELLOWS invented by Dr. *Nooth*, for the purpoſe of filling the blow-pipe with common or dephlogiſticated air. Theſe are to be fixed by the operator to the table by the braſs clamp *y*. He then joins the mouth *m* of the flexible tube to the larger extremity of a blowpipe, paſſing each orifice, through the leather tube *fig.* 18, and

and tying both ends with a waxed thin pack-thread. If he works with his foot on the pedal, the ſtring of which is ſeen hanging from the end of the bellows, *fig.* 14, (and is always up on account of the weight *e*) then the air is abſorbed by the bellows *fig.* 14, from whence it is propelled by the motion of the foot on the pedal, to the bellows *fig.* 15, whoſe conſtant weight *c* drives it out through the flexible pipe *fig.* 17: it of courſe enters the curved part of the blow-pipe, and drives the flame on the piece of the ore that is to be examined upon the charcoal.

N. B. 1. This double bellows is packed up by itſelf in a mahogany caſe, about 9 inches long, 6½ wide, and about 3½ deep, outſide meaſure.

N. B. 2. The laſt blowing bellows, *fig.* 15, has an inſide valve, which opens, when the upper ſurface of it is at its greateſt height in order to let the ſuperfluous air eſcape out, as it would otherwiſe iſſue with great velocity out of the tube *fig.* 17, and ſpoil the operation.

If the operator chuſes to apply the *vital* or *dephlogiſticated* air in his proceſs, let him fill the glaſs-jar *h*, *fig.* 19, with this air; and put it within the tub marked by *a b z e*, filled with water, faſtening the neck of the jar within by a croſs-board *cd*, which has a hole in it for that purpoſe; then introducing the two ends of the flexible hollow tube (*fig*, 16) both to the mouth of the jar, and to the hole of the bellows, *fig.* 14, he opens the hole *m* of the jar, that was ſtopped with the ſtopple *n*; the column of the water paſſes in through *m* and forces up the *vital air*, which enters the bellows, and of courſe, by the alternate motion of the pedal, paſſes through the end of the blow-pipe, to urge the flame upon the piece of ore on the charcoal.

But the *dephlogiſticated air* may be alſo received at the ſame time, that it is produced, by tying the pipe, *fig.* 16, to the mouth of an earthen retort, or of ſuch a porcelain-ware as that from Mr. *Wedgewood's* manufactory, or even of a glaſs retort well coated, according to the method of Mr. *Willis* deſcribed in the Tranſactions of the Society of Arts, Vol. V. p. 96. This laſt conſiſts in diſſolving two ounces of borax in a pint of boiling water, and adding to the ſolution as much ſlaked lime as is neceſſary to form a thin paſte: this glaſs retort is to be covered all over with it, by means of a painter's bruſh, and then ſuffered to dry. It muſt then be covered with a thin paſte of *linſeed oil* and *ſlaked lime*, except the neck that enters into the receiver. In two or three days it will dry of itſelf; and the retort will then bear the greateſt fire, without cracking. Two ounces of good nitre, being urged in the retort, by a good fire on a chaffing diſh, will afford about 7 or 800 ounce-meaſures of dephlogiſticated air. See *Prieſtley's* Experiments on Air, Vol. III, (or VI.) of his Philoſ. Works, p. 295.

THE END.

NOTE

# NOTE

*Referred to at page 437, but omitted there for want of room.*

"All *iron*, that, when made *red-hot*, becomes harder by being *haſtily quenched in cold water*, is called *ſteel*." This ſingle characteriſtic ſuffices for the diſtinguiſhing of ſteel from the ſofteſt iron; which, on being made red-hot, and quenched in like manner, does not become ſenſibly harder, but after this may be bent, as likewiſe be hammered and filed both hot and cold, almoſt as eaſily as before. As ſoon as iron, in conſequence of being made red-hot, and cooled quickly, becomes in a ſenſible degree more inflexible, brittle, and hard, it already partakes of the nature of *ſteel*. It is true, cold-ſhort iron, likewiſe becomes brittle after being hardened, but does not acquire a greater degree of hardneſs than it had before, when it was equally brittle. *Steel*, on the contrary, ſhould, both cold and hot, be almoſt as malleable, before it is hardened, as iron, and after being hardened, recover this malleability in conſequence of freſh ignition; ſtill, however, it is *more or leſs tough* in proportion to its hardneſs. That *ſteel*, which in quenching, acquires the greateſt *hardneſs* in the loweſt degree of *heat*, and retains the greateſt ſtrength in and after *induration*, may be fairly conſidered as the *beſt*.

The other characters by which ſteel is diſtinguiſhed from iron are as follows: (1) After being *furbiſhed*, ſteel appears of a whiter, light-grey hue, without the blue caſt exhibited by iron. It alſo takes a higher poliſh. (2) The hardeſt ſteel when not annealed, appears granulated, but dull and without ſhining fibres. (3) When ſteeped in acids, the harder the ſteel is, of a darker grey hue is its ſurface. (4) Steel is not ſo much inclined to ruſt as iron. (5) In general ſteel has a greater ſpecific gravity. (6) By being hardened and wrought, it may be rendered much more *elaſtic* than iron. (7) When indurated it becomes more ſonorous than iron. (8) When furbiſhed, it appears more cloſe and denſe than iron. (9) It is not attracted ſo ſtrongly by the magnet as ſoft iron is. It likewiſe acquires magnetic properties more ſlowly, but retains them longer; for which reaſon ſteel is uſed in making needles for compaſſes and artificial magnets. (10) By hammering and friction it acquires a greater magnetic power than iron does. (11) In heat, ſteel expands more than iron. (12) By induration, or quenching in water, it retains nearly the ſame bulk as it had acquired in heat, or, at leaſt, contracts very little; while, on the other hand, iron contracts to the ſame ſpace as it took up before it was ignited. (13) Steel is ignited ſooner, and fuſes with a leſs degree of heat than malleable iron, which can ſcarcely be made to fuſe without the addition of powdered charcoal, by which it is converted into ſteel, and afterwards into crude iron. (14) By a particular management it may be fuſed and caſt, and yet continue to be malleable, which is ſcarcely the caſe with ſoft iron. (15) Poliſhed ſteel is ſooner tinged by heat, and that with higher colours, than iron. (16) In a calcining heat it ſuffers leſs loſs by burning, than ſoft iron does in the ſame heat and the ſame time. In calcination, a light blue flame hovers over the ſteel, either with or without a ſulphureous odour. (17) The ſcales of ſteel are harder and ſharper than thoſe of iron, and conſequently more fit for poliſhing with. (18) In a white heat, when expoſed to the blaſt of the bellows, among the coals, it begins to ſweat, weld, or melt, partly with light-coloured and bright, and partly with red ſparkles, but leſs crackling than thoſe of iron; in a melting heat too it conſumes faſter. (19) By much welding, annealing,

annealing, and hammering in a flow but ftrong heat, fteel is converted into iron; cement fteel fooner, and caft fteel later. (20) Covered with powdered charcoal preffed down clofe upon it, and expofed to a ftrong heat, it acquires a flight coat, refembling black lead. By being frequently burned it becomes as brittle as crude iron. (21) Digefted with water in clofe veffels, it appears to yield a fmaller quantity of inflammable air than iron. (22) Diffolved in vitriolic acid, it yields lefs inflammable air than foft iron does. (23) In the vitriolic, nitrous, and other acids, fteel, it is true, is violently attacked, but is longer in diffolving than iron; after maceration, accordingly as it is fofter or harder, it appears of a lighter or darker grey colour, while iron, on the other hand, is white. (24) In the folution of fteel in acids, a fmaller degree of heat is produced than with tough, and ftill weaker than with cold-fhort iron. (25) It requires more nitrous acid for its complete folution. (26) In the cold it is proportionably harder, and more brittle, or lefs malleable than pure iron. (27) In detonating with falt-petre, it yields more fixed air than malleable iron does.

Steel differs from crude iron chiefly in malleability, a quality which is intirely wanting in the latter, both cold and hot; ftill, however, they both agree in many particulars, as for inftance: (*a*) Crude iron, after being melted over again, and polifhed, acquires as light and white a hue as fteel. (*b*) They both acquire a variegated vitreous coat in the fire. (*c*) Crude iron alfo becomes magnetic, though more flowly, than fteel. (*d*) After being fubjected to a red heat, it becomes harder by being extinguifhed in water, and particularly, when melted and immediately thrown into water. (*e*) It melts eafier than fteel, and much eafier than forged iron. (*f*) When indurated, it ftrikes fire with flints, though the fparks produced by it are fomewhat weaker than thofe generated by fteel. (*g*) Crude iron appears to yield as much inflammable air as fteel, by digeftion in water. (*h*) It likewife depofits a black fediment, when macerated in acids. (*i*) It rufts in the air as flowly as fteel. (*k*) When caft, it rings like fteel.

Vid. *Rinman*, Forfoek till Jarnets Hiftoria. §§. 257, 258.

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# SINGLE ELECTIVE ATTRACTIONS.

## *IN THE HUMID WAY.*

### ACIDS.

| | Vitriolic Nitrous Marine 1 | Acetous Galactic Myrmecic 2 | Aerial 3 | Electrine 4 | Cyanotic 5 | Fluoric Oxaline Tartaric 6 | Arsenical Boracic Citreous Sebaceous Benzoic Galamel$^{c}$ Phosphor$^{c}$ 7 |
|---|---|---|---|---|---|---|---|
| 1 | Barytes | * | * | * | Fixed alkali | Lime | * |
| 2 | Fixed alkali | * | Lime | * | Volat.alkali | Barytes | * |
| 3 | Lime | Volat.alkali | Fixed alkali | Murioecite | Lime | Murioecite | * |
| 4 | Murioecite | Lime | Murioecite | Fixed alkali | Barytes | Fixed alkali | * |
| 5 | Volat.alkali | Murioecite | Volat.alkali | * | Murioecite | Volat.alkali | * |
| 6 | Alumite* | * | * | * | * | * | * |
| 7 | ¥ Zinc | * | * | * | * | * | * |
| 8 | ¥ Iron | * | * | * | * | * | * |
| 9 | ¥ Mangan$^{e}$ | * | * | * | * | * | * |
| 10 | ¥ Cobalt | * | * | * | * | * | * |
| 11 | ¥ Nickel | * | * | * | * | * | * |
| 12 | ¥ Lead | * | * | * | * | * | * |
| 13 | ¥ Tin | * | * | * | * | * | * |
| 14 | ¥ Copper | * | * | * | * | * | * |
| 15 | ¥ Bismuth | * | * | * | * | * | * |
| 16 | ¥ Antimony | * | * | * | * | * | * |
| 17 | ¥ Arsenic | * | * | * | * | * | * |
| 18 | ¥ Mercury | * | * | * | * | * | * |
| 19 | ¥ Silver | * | * | * | * | * | * |
| 20 | ¥ Gold | * | * | * | * | * | * |
| 21 | ¥ Platina | * | * | * | * | * | * |
| 22 | Water | * | * | * | * | * | * |
| 23 | Alcohol | * | * | * | * | * | * |
| 24 | Phlogiston | * | Volatile oils | Phlogiston | | [Silicite] | Phlogiston |
| 25 | | | Fixed oils | | | [FLUORIC] *only* | |

### INCOMBUSTIBLES.

| | Alkalies 8 | Barytes 9 | Lime 10 | Murioecite 11 | Alumite 12 | Silicite 13 | Water 14 |
|---|---|---|---|---|---|---|---|
| 1 | Vitriolic+ | * | Oxaline+ | Oxaline+ | Vitriolic+ | Fluoric+ | Fixed alkali |
| 2 | Nitrous+ | Oxaline+ | Vitriolic+ | Phosphor$^{c}$+ | Nitrous+ | Fixed alkali | Volat.alkali |
| 3 | Marine+ | Electrine+ | Tartaric+ | Vitriolic+ | Marine+ | | Alcohol |
| 4 | Sebaceous+ | Fluoric+ | Electrine+ | Fluoric+ | Oxaline+ | | Mild v. alkali |
| 5 | Fluoric+ | Phosphor$^{c}$+ | * | Sebaceous+ | Arsenical+ | | Glauber salt |
| 6 | Phosphor$^{c}$+ | Galamel$^{c}$+ | * | Arsenical+ | Fluoric+ | | Æther |
| 7 | Oxaline+ | Nitrous+ | * | Galamel$^{c}$+ | Sebaceous+ | | |
| 8 | Tartaric+ | Marine+ | * | Electrine+ | Tartaric+ | | |
| 9 | Arsenical+ | Sebaceous+ | * | Nitrous+ | Electrine+ | | |
| 10 | Electrine+ | Citreous+ | Fluoric+ | Marine+ | Galamel$^{c}$+ | | |
| 11 | Citreous+ | Tartaric+ | Arsenical+ | Tartaric+ | Citreous+ | | |
| 12 | Myrmecic+ | Arsenical+ | Myrmecic+ | Citreous+ | Phosphor$^{c}$+ | | |
| 13 | Galactic+ | Myrmecic+ | Galactic+ | Myrmecic+ | * | | |
| 14 | Benzoic+ | Galactic+ | Citreous+ | Galactic+ | * | | Vitriolic+ |
| 15 | Acetous+ | Benzoic+ | * | * | * | | Vitriol tart. |
| 16 | Galamel$^{c}$+ | Acetous+ | * | * | * | | Alum |
| 17 | Boracic+ | * | * | * | * | | Mart.vitriol |
| 18 | Sulphuric+ | * | * | * | * | | Cor.sublim. |
| 19 | Aponitrous+ | * | * | * | * | | |
| 20 | Aerial+ | * | * | * | * | | |
| 21 | Cyanotic+ | * | * | * | * | | |
| 22 | * | * | * | | | | |
| 23 | Fixed oils | * | * | | | | |
| 24 | Sulphur | * | * | * | | | |
| 25 | Metallic ¥ | | | | | | |

### COMBUSTIBLES.

| | Phlogiston 15 | Sulphur 16 | Sal. Hepar 17 | Alcohol 18 | Æther 19 | Vol. Oils 20 | Fixed Oils 21 |
|---|---|---|---|---|---|---|---|
| 1 | Nitrous+ | ¥ Lead | ¥ Gold | Water | Alcohol | Æther | * |
| 2 | Vitriolic+ | ¥ Tin | ¥ Silver | Æther | Volatile oils | Alcohol | Volatile oils |
| 3 | Epimuriat$^{c}$+ | ¥ Silver | ¥ Mercury | Volatile oils | Fixed oils | * | Fixed alkali |
| 4 | Arsenical+ | ¥ Mercury | ¥ Arsenic | Vol. alkali | Water | Fixed alkali | Vol. alkali |
| 5 | Phosphor$^{c}$+ | ¥ Arsenic | ¥ Antmony | Fixed alkali | Sulphur | * | * |
| 6 | | ¥ Antmony | ¥ Bismuth | Saline hepar | | | |
| 7 | ¥ Platina | ¥ Iron | Copper | Sulphur | | | |
| 8 | ¥ Gold | Fixed alkali | ¥ Tin | | | | |
| 9 | ¥ Silver | Vol. alkali | ¥ Lead | | | | |
| 10 | ¥ Mercury | Barytes | ¥ Nickel | | | | |
| 11 | ¥ Arsenic | Lime | ¥ Cobalt | | | | |
| 12 | ¥ Antimony | Murioecite | ¥ Manganese | | | | |
| 13 | ¥ Bismuth | | ¥ Iron | | | | |
| 14 | ¥ Copper | | | | | | |
| 15 | ¥ Tin | | | | | | |
| 16 | ¥ Lead | | | | | | |
| 17 | ¥ Nickel | | | | | | |
| 18 | ¥ Cobalt | | | | | | |
| 19 | ¥ Manganese | | | | | | |
| 20 | ¥ Iron | | | | | | |
| 21 | ¥ Zinc | | | | | | |
| 22 | | Fixed oils | | | | | |
| 23 | | Volatile oils | | | | | |
| 24 | | Æther | Alcohol | | | | |
| 25 | Water | Alcohol | Water | | | | |

### METALLIC SUBSTANCES.

| | ¥ Gold 22 | ¥ Platina 23 | ¥ Silver 24 | ¥ Mercury 25 | ¥ Lead 26 | ¥ Copper 27 | ¥ Iron 28 |
|---|---|---|---|---|---|---|---|
| 1 | * | * | Marine+ | Sebaceous+ | Vitriolic+ | Oxaline+ | * |
| 2 | Marine+ | * | Sebaceous+ | Marine+ | Sebaceous+ | Tartaric+ | * |
| 3 | Aqua regia | * | Oxaline+ | * | Galamel$^{c}$+ | Marine+ | Vitriolic+ |
| 4 | Nitrous+ | * | Vitriolic+ | Electrine+ | Oxaline+ | Vitriolic+ | Galamel$^{c}$+ |
| 5 | Vitriolic+ | * | Galamel$^{c}$+ | Arsenical+ | * | Galamel$^{c}$+ | Marine+ |
| 6 | Arsenical+ | * | Phosphor$^{c}$+ | * | Tartaric+ | Nitrous+ | * |
| 7 | Fluoric+ | * | Nitrous+ | Vitriolic+ | Phosphor$^{c}$+ | Sebaceous+ | * |
| 8 | Tartaric+ | * | Arsenical+ | Galamel$^{c}$+ | Marine+ | Arsenical+ | Phosphor$^{c}$+ |
| 9 | Phosphor$^{c}$+ | * | Fluoric+ | Tartaric+ | Nitrous+ | Phosphor$^{c}$+ | Arsenical+ |
| 10 | Sebaceous+ | * | Tartaric+ | Citreous+ | Fluoric+ | Electrine+ | Fluoric+ |
| 11 | Cyanotic+ | Oxaline+ | Citreous+ | Nitrous+ | Citreous+ | Fluoric+ | Electrine+ |
| 12 | | Citreous+ | Myrmecic+ | Fluoric+ | Myrmecic+ | Citreous+ | * |
| 13 | | Myrmecic+ | Galactic+ | Acetous+ | Galactic+ | Myrmecic+ | * |
| 14 | | Galactic+ | Acetous+ | Boracic+ | Acetous+ | Galactic+ | * |
| 15 | | Acetous+ | Electrine+ | Cyanotic+ | Boracic+ | Acetous+ | * |
| 16 | | Electrine+ | Cyanotic+ | Aerial+ | Cyanotic+ | Boracic+ | * |
| 17 | | | Aerial+ | | * | Cyanotic+ | * |
| 18 | | | | | | Aerial+ | * |
| 19 | Fixed alkali * | | | | | Fixed alkali | |
| 20 | Volat.alkali | | | | | Volat.alkali | |
| 21 | | * | | | | | |
| 22 | | | | | | * | |
| 23 | | | | | | | |
| 24 | | | | | | | |
| 25 | | | | | | | |

| | ¥ Tin 29 | ¥ Bismuth 30 | ¥ Nickel 31 | ¥ Arsenic 32 | ¥ Cobalt 33 | ¥ Zinc 34 | ¥ Antim.$^{y}$ 35 | ¥ Magnese 36 | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Sebaceous+ | Oxaline+ | * | Marine+ | Oxaline+ | * | Sebaceous+ | Oxaline+ | 1 |
| 2 | * | Arsenical+ | Marine+ | Oxaline+ | Marine+ | Vitriolic+ | Marine+ | Citreous+ | 2 |
| 3 | Marine+ | Tartaric+ | Vitriolic+ | * | Vitriolic+ | Marine+ | Oxaline+ | Phosphor$^{c}$+ | 3 |
| 4 | Vitriolic+ | Phosphor$^{c}$+ | Tartaric+ | Nitrous+ | Tartaric+ | Galamel$^{c}$+ | Vitriolic+ | Tartaric+ | 4 |
| 5 | Oxaline+ | Vitriolic+ | Nitrous+ | Sebaceous+ | Nitrous+ | * | * | Fluoric+ | 5 |
| 6 | Arsenical+ | Sebaceous+ | * | Tartaric+ | Sebaceous+ | * | Tartaric+ | Marine+ | 6 |
| 7 | Phosphor$^{c}$+ | Marine+ | Phosphor$^{c}$+ | * | * | Tartaric+ | Galamel$^{c}$+ | Vitriolic+ | 7 |
| 8 | Nitrous+ | * | Fluoric+ | * | * | Phosphor$^{c}$+ | * | Nitrous+ | 8 |
| 9 | Electrine+ | Fluoric+ | Galamel$^{c}$+ | * | * | Citreous+ | * | Galamel$^{c}$+ | 9 |
| 10 | * | Galamel$^{c}$+ | Electrine+ | * | * | * | * | Electrine+ | 10 |
| 11 | Galamel$^{c}$+ | Electrine+ | Citreous+ | * | * | Fluoric+ | * | Sebaceous+ | 11 |
| 12 | * | * | Myrmecic+ | * | * | Arsenical+ | * | * | 12 |
| 13 | * | * | Galactic+ | * | * | Myrmecic+ | * | * | 13 |
| 14 | * | * | Acetous+ | Arsenical+ | Acetous+ | Galactic+ | * | * | 14 |
| 15 | * | * | Arsenical+ | Acetous+ | Arsenical+ | Acetous+ | * | * | 15 |
| 16 | * | | * | | * | * | * | | 16 |
| 17 | * | * | * | * | * | * | * | * | 17 |
| 18 | | * | * | | * | * | * | * | 18 |
| 19 | * | | | | | | | | 19 |
| 20 | * | * | * | * | * | | | | 20 |
| 21 | | | | | | | | | 21 |
| 22 | | | | * | | | | | 22 |
| 23 | | | | | | | | | 23 |
| 24 | | | | | | | | | 24 |
| 25 | | | | * | | | | | 25 |

# SINGLE ELECTIVE ATTRACTIONS.

## *IN THE DRY WAY.*

| | ACIDS. | | | | INCOMBUSTIBLES. | | | COMBUSTIBLES. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Vitriolic Nitrous Marine 1 | Fluoric Boracic Galamel^c Sebaceous Phosphor^c 2 | Electrine 3 | Acetous Galactic Myrmecic 4 | Alkalies 5 | Earths 6 | Silicite 7 | Phlogist^n 8 | Sulphur 9 | Sal. hepar 10 |
| 1 | Phlogiston | Lime | Barytes | Barytes | Phosphor^c + | * (Fixed alkal. only) | | ☿ Platina | Fixed alkali | Manganese |
| 2 | Barytes | * | Lime | Fixed alkali | Boracic + | * | | ☿ Gold | Iron | * |
| 3 | Fixed alkali | Murioecite | * | Lime | Arsenical + | * | | Arsenical + | Copper | * |
| 4 | Lime | Fixed alkali | * | Murioecite | Vitriolic + | * | | ☿ Silver | Tin | * |
| 5 | Murioecite | Metallic ☿ | * | * | Nitrous + | Electrine + | | ☿ Mercury | Lead | * |
| 6 | Metallic ☿ | Volat. alkali | * | * | Marine + | Fluoric + | | ☿ Arsenic | Silver | * |
| 7 | Volat. alkali | Alumite | * | * | Sebaceous + | Nitrous + | | ☿ Antimony | Cobalt | Gold |
| 8 | Alumite | [Silicite] | | | Fluoric + | Marine + | | ☿ Bismuth | Nickel | Antimony |
| 9 | | [BORACIC] only | | | Electrine + | Sebaceous + | | ☿ Copper | Bismuth | Cobalt |
| 10 | | | | | Myrmecic + | * | | ☿ Tin | Antimony | Nickel |
| 11 | | | | | Galactic + | * | | ☿ Lead | Mercury | Bismuth |
| 12 | | | | | Benzoic + | * | | ☿ Nickel | Arsenic | Mercury |
| 13 | | | | | Acetous + | * | | ☿ Cobalt | | Arsenic |
| 14 | | | | | Barytes | | | ☿ Mangan^e | | |
| 15 | | | | | Lime | Fixed alkali | * | ☿ Iron | | |
| 16 | | | | | Murioecite | | Boracic + | ☿ Zinc | | |
| 17 | | | | | Alumite | Sulphur | Phosphor^c + | | | |
| 18 | | | | | Silicite | | | | | |
| 19 | | | | | Sulphur | ☿ Lead | * | | | |

| | METALLIC SUBSTANCES. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gold 11 | Platina 12 | Silver 13 | Mercury 14 | Lead 15 | Copper 16 | Iron 17 | Tin 18 | Bismuth 19 | Nickel 20 | Arsenic 21 | Cobalt 22 | Zinc 23 | Antimony 24 | Manganese 25 |
| 1 | Mercury | Arsenic | Lead | Gold | * | * | Nickel | Mercury | Lead | Iron | Nickel | Iron | Copper | Iron | Copper |
| 2 | Copper | Gold | Copper | Silver | * | * | Cobalt | Copper | Silver | Cobalt | * | Nickel | Antimony | Copper | Iron |
| 3 | Silver | Mercury | * | Platina | Copper | Arsenic | Manganese | Antimony | Gold | Arsenic | Copper | Arsenic | Tin | * | Gold |
| 4 | Lead | Tin | Bismuth | Lead | Mercury | Iron | Arsenic | Gold | Mercury | Copper | Iron | Copper | Mercury | Lead | Silver |
| 5 | Bismuth | * | Tin | * | Bismuth | Manganese | Copper | Silver | Antimony | Gold | Silver | Gold | Silver | Nickel | Tin |
| 6 | Tin | Zinc | Gold | Zinc | Tin | Zinc | Gold | Lead | Tin | * | * | Platina | Gold | Silver | |
| 7 | Antimony | * | * | Bismuth | Antimony | * | Silver | Iron | Copper | Antimony | Lead | Tin | Cobalt | Bismuth | |
| 8 | Iron | Nickel | Iron | Copper | Platina | * | Tin | Manganese | Platina | * | Gold | Antimony | Arsenic | Zinc | |
| 9 | Platina | Cobalt | Manganese | Antimony | Arsenic | Tin | Antimony | Nickel | * | Bismuth | Platina | Zinc | Platina | Gold | |
| 10 | Zinc | Manganese | Zinc | Arsenic | Zinc | Lead | Platina | Arsenic | Iron | Lead | Zinc | | Bismuth | Platina | |
| 11 | Nickel | Iron | Arsenic | Iron | Nickel | * | Bismuth | Platina | Zinc | Silver | Antimony | | Lead | Mercury | |
| 12 | Arsenic | Lead | Nickel | | Iron | Bismuth | Lead | Bismuth | | Zinc | | | Nickel | Arsenic | |
| 13 | Cobalt | Silver | Platina | | | ☿ Cobalt | Mercury | Cobalt | | | | | Iron | Cobalt | |
| 14 | Manganese | Mercury | | | | * | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | |
| 16 | Sal^ne. hepar | * | * | * | * | * | * | * | * | * | * | * | | * | * |
| 17 | | | Sulphur | * | * | * | * | * | * | * | * | * | | * | |
| 18 | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | |

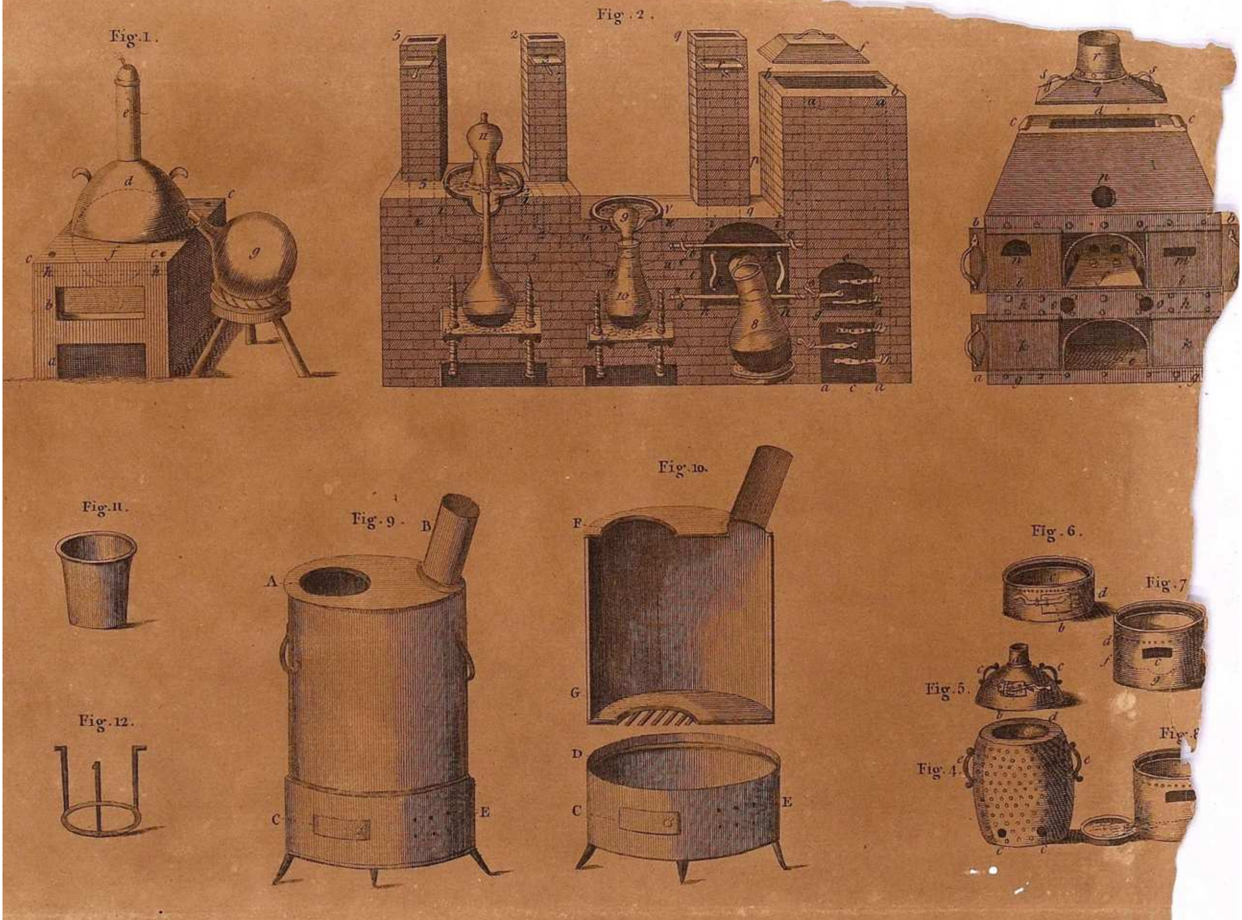
Fig. 1.
Fig. 2.
Fig. 11.
Fig. 9.
Fig. 10.
Fig. 6.
Fig. 7
Fig. 5.
Fig. 4.
Fig. 12.

PLATE II.

Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
Fig. 19.
Fig. 20.
Fig. 21.
Fig. 22.